This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

600045852U

G.63. B. 3.

E. BIBL. RADCL.

C
18811 d. 91

15811 d 91

FACTS

AND

OBSERVATIONS

TOWARDS FORMING

A NEW THEORY OF THE EARTH.

By WILLIAM KNIGHT, LL. D.

PROFESSOR OF NATURAL PHILOSOPHY IN THE INSTITUTION
OF BELFAST.

Multum adhuc restat operis, multumque restabit, nec ulli nato post mille secula præcludetur occasio aliquid adjiciendi.

Seneca.

EDINBURGH:
PRINTED FOR ARCHIBALD CONSTABLE & CO. EDINBURGH;
LONGMAN, HURST, REES, ORME & BROWN, AND
HURST, ROBINSON & CO. LONDON.

1819.

P. Neill, Printer.

ADVERTISEMENT.

The following Pages were written to present an outline of the Facts and Observations which the Author regards as tending to assist in the formation of a New Theory of the Earth. Though they are only the abridgment of a larger work, which he has been long preparing, yet in some parts he has been induced to enter into such details as may render them useful as an Introduction to Geology, from their containing those facts and arguments which the present state of the Science has supplied.

He has seen, a few days ago, in Dr Thomson's Annals of Philosophy for the present month, a notice of a Paper having been read in April last to the Geological Society of London, by A. S. Lillington, Esq. on Granite Veins and Whin Dykes, in which the appearances are explained, upon the supposition that the beds containing the Veins were deposited upon the mass of which the vein is a portion, while that mass was in a fluid state; and that the deposited beds were the first to become hard, in consequence of which they contracted, thus occasioning fissures, which were subsequently filled by the subjacent fluid mass.

This explanation appears to be the same with that given by the Author of the following Work, though he is ignorant of the data upon which it is founded. The leading ideas contained in these pages were read by him to a Scientific Society in the beginning of September last year. He is, however, far more solicitous for proofs of the truth of his observations, than desirous of priority of discovery, in a subject, where several of the inferences which he has ventured to draw, may have occurred to other observers.

30*th July* 1818.

CONTENTS.

I. INTRODUCTION.

Intimate connection of Geology with Mineralogy and Chemistry, - - *Page* 2
The progress of this Science not to be despaired of, - - - 3
Peculiar Interest attached to studying it, - 4
The old theories of the Earth entirely hypothetical, the modern ones more descriptive, - 6
Importance of the phænomena of Geology, 8
Theory of WERNER, - - 10
Some objections to it, - - 11
Short view of the HUTTONIAN Theory, - 13
Objections, - - - 16
Its advantages in explaining some appearances, 18
Some advantages of both theories, - 19
Both useful, though unsatisfactory in their first principles, - - - 23
Disadvantages of hypothesis alone in leading to a system of exact Science, - - 25

Page

II. Most of the tests of an Aqueous or Igneous origin of Minerals that have been hitherto stated, unsatisfactory, 30

Appearances observed in rocks whose *colours* arise from Iron, proposed as a mark of their origin, ib.

The distribution of oxide of iron in the materials of granite, incompatible with an aqueous crystallization, - - - 33

But agreeing well with observations on the action of heat, in separating oxide of iron in different parts of the same mass, - 35

Objection, from the definite proportions in which the constituent parts of minerals unite, 38

Corroborating appearances observed in the vicinity of granite veins and whin-dykes, in producing changes of colour in them, and in the rocks which they traverse, - 40

III. The Nature of Rocks proposed as a test of their origin, - - 44

Granite described;—often contains hornblende, 45

In the mountain-mass it is unstratified, and appears in distinct concretions, - 47

Gneiss, or slaty granite, - - 51

Quartz Rock, - - - 52

Mica-slate, - - - 56

Clay-

Page
Clay-slate, - - - 56
Primary Limestone, - - ib.
Primary Trap, Serpentine, &c. - ib.
Porphyry, often unstratified, and much neglected, - - - - 57
The Huttonian Theory destitute of an explanation of the nature and order of these primary strata, - - - 61
All theories admit the agency of Water in their formation, - - - 62
In all fragmented rocks, an origin from more primary ones may be inferred, - ib.
QUESTIONS which at the present day it is necessary to explain in a Theory of the Earth, 63
1. Proofs of unstratified Granite having been formed in a mode different from that of the stratified rocks, from its position, veins, structure, &c. - - - 65
2. The constant relation between the materials of the stratified rocks, and the constituent parts of Granite, described, - 69
  In nature of mineral substance, all the strata can be traced to Granite, - 72
  And hence their origin from it inferred, ib.
3. This relation the closer, the nearer the position of the strata to the unstratified Granite, 73

4. Proofs

Page
4. Proofs of the origin of the primary strata by a mechanical deposition of the materials of granite, - - - 74
Mechanical appearances visible in mica-slate, quartz rock, clay-slate, &c. - 75
The constant passages of these rocks into each other, an evidence of mechanical deposit, 77
The varying size of the grains of gneiss, mica-slate, &c. another proof of this, - 78
Experimental proof of the deposit of the chief primary rocks in the order of Werner nearly, by mechanical means, - - 80
Proof of mechanical deposit, from the *outgoings* of the strata, - - 82
From the alternations of beds of different substances, - - - 84
From the alternations of thick and thin strata, 86
An uniform regularity in the *direction* of strata, inconsistent with their elevation from great depths by heat, - - 86
But a necessary consequence of a mechanical deposit, - - - 89
Its connection with the rotation of the Globe, 90
Last proof, of mechanical origin from water. possessing the mechanical powers requisite, but no chemical

Page
chemical agency in dissolving the materials of the strata, - - 92
Proofs of water having existed at the formation of the strata, - - 93

IV. Nature of CRYSTALLINE AGGREGATION.

All the strata, from the oldest to the newest, enclose crystals, - - 95
These crystals often of cotemporaneous or subsequent formation to the rocks which enclose them, - - - 96
Attempts to account for this appearance by Berzelius, and others, - - ib.
Proofs of the mechanical transference of matter in the formation of crystals, and that no solution in water of the whole substance of the crystal is necessary for its formation, - 99
Formation of crystals in this mode going on at the present day, - - 105
Crystallization performed by hygrometric water in alum-slate, - - 106
Inference, that the deposit of matter in the formation of many crystals is of as mechanical a nature as their structure, - 108
Graphic Granite, and similar appearances, not explicable

Page
plicable on any principles of heat, or solution in water, hitherto brought forward, - 109
Attempt to explain them, - ib.
And to account for the existence of perfect organic remains attached to regular crystals, 110
On the formation of Agates, *note*, - 114
Conclusion, that nothing in the crystalline structure of minerals affords evidence of either aqueous or igneous origin, - 115

V. Igneous origin of Granite; proofs of it from colour, from the appearances of veins, &c. - - - 116
The presence of highly elastic steam will account for the alternation of consolidated and unconsolidated strata, - - 119
Convolutions and Wavings of the Strata, 121
Statement of the two proofs of the metallic nature of the interior of the Globe, - 124
The *first formations* of rocks must have been igneous, - - 127
Figure of the Earth, - - 128
Conclusions from the above principles; formation of all stratified rocks by disintegration of granite under water, and consolidation by heat, 129
Note on the Observations made by the Author, 133

VI. BASALT

Page

VI. Basalt and Trap Rocks.

Their importance in Geological science, - 136

Proofs of their Origin deduced from—

1. The separation of colour in their fragments, 137
2. The nature of their substance, and their transitions, - - - 138
3. Their numerous relations to Granite, 140
4. And to Lavas, - - 145
5. Their being often unstratified, like granite, 151
6. The nature of their structure, in distinct concretions, - - - ib.

Description of several appearances in the Giant's Causeway, - - - 153

Dissection of the joints of the columns, - 156

Result;—a compressed spheroid inclosed in each joint, - - - 157

This spheroid itself of concentric and radiated structure, - - ib.

The *nature* of the rock related to its more or less perfect *form* of column, - 159

Conclusions from the appearance of the same structure in crystallized glass, - ib.

And in glass-house scoriæ, - 161

Mr Watt's experiments on the fusion of basalt in 1804, - - - ib.

Formation of spheroids in it when cooling, and transition

Page
transition from these through a prismatic, compact, and granular texture, till crystals appear, 162
The same spherical structure visible in minerals of aqueous formation, - - 165
The subject of CRYSTALLIZATION resumed, 166
Proofs, that a compound nature of substance prevents the formation in many cases of regular rectilineal crystals, - - 167
Causes of which the action may be inferred in this process, - - - 171
No proof of aqueous or igneous origin in this structure of Basalt, - - 173
7. Unstratified Traps the highest and lowest rocks observed in the countries where they occur, 174
Proofs of this, - - 175
From the phænomena of whin-dykes, - 180
From instances of compression in dislocating the strata, - - - 183
Debacle of Basalt, - - 184
Red-ochre or clay of the Antrim coast, - 186
Its relations to Basalt; its formation by disintegration of Basalt under water and consolidation by heat, - - - 187
Reasons for Basalt being a newer formation than Granite, - - - 189
8. *Whin-Dykes* a proof of igneous origin, - 190

Description

Page
Description of them, - - 190
Simple, Compound, and Amorphous dykes, 191
Division into three kinds, from the nature of the fissures, - - - - 193
9. Phænomena at the Junctions of Whin-Dykes with the strata which they cut, one of the best tests of igneous origin, - - 195
List of the appearances observed at these, - ib.
The Neptunian explanation insufficient, - 197
10. Existence of Surturbrand, or Wood-coal, in Basaltic Collonades, - - 198
11. Cinders at the Causeway, - 199
12. Action of heat in the appearances observed in shells in the altered limestone near whin-dykes, 201
The shells of Portrush, - - 202
Inference from their graduating into the substance of the siliceous slate, - ib.
13. Water in the cavities of Basalt, - 203
14. Minerals included in Trap rocks, - 204
Conclusion, - - - 206

VIII. TRANSITION AND SECONDARY ROCKS, 207
General ideas of their origin, from the disintegration of more primary strata, - 211
Organic remains of Shells, - - 213
Mr Parkinson's Conclusions, - 214

Only

Page
Only one formation of shells, - 216
The process of Petrifaction illustrated by the mechanical deposit of silicеous, calcareous, or argillaceous matter in the organic mould, *note*, 217
Inferences of rapidity in this change, - ib.
Of Coal, - - - 218
The Proofs of its origin from wood, - 219
Dr MacCulloch's discovery on this subject, 220

VIII. General Ideas of the formation of the exterior parts of the Earth, on the preceding views, - - 222
Summits of granite mountains at the present day, 227
Marks of the last transit of the waters, - 228
Valleys modelled by larger streams than now roll in them, - - - 230
Progress of rivers through the strata, from the mountain top to the plains of the ocean, ib.
Interest of Geological Science, when attached to the sublime scenery of Nature, - 237
Remarks on the distribution of the Mountain-land of the Globe, - - 238
Volcanoes, - - - 240
Transportation of Materials, - 241
Their most probable explanations, - 243

Page

IX. Destroying and Renovating Powers, 245

Mechanical destruction of Rocks described, 246

Disintegration of Granite and Basalt, - ib.

Utility of this decay, - - 248

It has its boundary in the constant formation of new land, - - - - 250

Causes which tend to preserve the mountains for an infinite series of years, - 253

Origin of some Islands by submarine fires, 254

Utility of Volcanoes in the System of the World, 255

Formation of new land by coral worms, - 257

Conclusion,—That the World having had its present arrangement from causes which do not now act, and being thus related to animals and plants, exhibits, like the succession of their generations, no traces of an end, - 258

X. Connection of Geology with the Scriptures, - - - 261

The early theorists resorted to them chiefly, and not to minerals, - - ib.

The consequences of this, even in later writers, 263

The Scriptures not intended to teach us any systems of Natural Knowledge, in Astronomy, Geography, Geology, &c. - 264

And

Page
And degraded when applied to confirm or oppose our geological theories, - 265
Well established facts may be applied to the Mosaic account, - - - 267
List of some of these, and the caution necessary in applying them, - - - ib.
Conclusion, - - - 269

ADDITIONAL NOTES.

System of Werner, - - 273
Consolidation of the Strata, - 284
Huttonian Theory, - - 291
Central Heat, - - 298
On the Experiments shewing that the Wernerian order of some of the Primary Strata is preserved in a mechanical deposit, - 300
Mechanical Structure of the Strata, - 301
On the formation of Stalactites, - 305
On the Huttonian and Wernerian explanations of particular minerals, and metallic veins, 313
Pitchstone Porphyry, - - 319
Disintegration of the Strata, - 320
Connection of Geology with the Scriptures, 325
Some Advantages of the New Theory, 329

FACTS AND OBSERVATIONS

TOWARDS FORMING

A NEW THEORY OF THE EARTH.

My Dear Sir,

You have so frequently requested me to give you some account of the ideas which I have been led to form for these some years past respecting geological subjects, that I have at last determined to offer to your consideration the following remarks. I beg that at the commencement of an undertaking which I cannot but regard as arduous, and even somewhat hazardous, you will believe, that though I have been long convinced of the truth of the principles which I am about to unfold, yet that I by no means regard them as approaching to a complete Theory of the Formation of the Earth. But they are principles which have constituted, as you know, a large part of my studies; and, after some detailed investigations, I am inclined to believe that they may assist in solving that problem, which has now become the most important in the whole range of the physical sciences.

The objects of GEOLOGY are indeed so numerous and varied, as fully to justify the eminence to which it has arisen in our own time. Though it may owe something to fashion or caprice for the rank which it now holds, yet it is impossible to deny, that the facts which it already enumerates are of great interest, and the conclusions to which they frequently lead, of mighty utility. Its intimate connection with CHEMISTRY and MINERALOGY has assisted to raise it to its present state. To one of these sciences it is indebted for the fundamental principles of many of its reasonings; and the other is so subservient to it, that it has been justly said, that "Mineralogy is the Alphabet "of Geology." The numerous aids which the Chemist has furnished to the mineral kingdom, have in many cases been applied to Geology; nor is there any fact or principle connected with the *nature* of material substance, which the Geologist may not render useful to his favourite pursuit. Hence, it may be safely affirmed, that, great as is the attention paid to this science at present, it will rank far higher in future times, when the number of its facts, constantly augmenting, shall have given a greater certainty to the theories which connect them into a body of knowledge; a certainty not unequal to that which is attainable in the rest of the sciences. We are too apt, indeed, to despair of Geology, from its having been, till very lately, little else than a collection of hypotheses, and from its being, at this moment, the newest of the sciences. If, however, we cast a glance at the number, the variety, the interest, and utility of the facts already known; if we consider what a rich harvest yet remains to be discovered, we may be allowed to infer, that, of all the sciences, Geology is that of the progress of which we should despair the least.

These remarks may be considered as independent of that fascinating influence felt in all ages by philosophers, and which has so often led them onward with enthusiasm to trace the nature and history of the world. Questions which were agitated by ANAXAGORAS and PLATO *, and embellished by LUCRETIUS; which even gave rise to some of the speculations of AUGUSTINE †, and which have been embodied in

---

* See the opinions of Anaxagoras in Enfield's History of Philosophy, vol. i. p. 160. The ideas of PLATO are perhaps best unfolded by BARTHELEMY, in the discourse which Plato is supposed to give from the Temple of Minerva at Sunium, on the formation of the world. *Travels of Anacharsis.*

† St Augustine found on the sea-shore near Utica a fossil tooth which he regarded as human, although a hundred times the ordinary size. The teeth of elephants, dug

in a greater or less degree with the popular and religious superstitions of all nations, must be possessed of some interest. The nature of the arrangement of the globe, in mountains and valleys, strata and veins; the occurrence of remains of organic beings in hard rocks, not rarely, or in small quantities, but in all countries, and often constituting the greater part of the strata; the changes of a slower or more rapid kind which whole tracts of country have undergone; all these have been applied, from the earliest times, to supply evidence to hypotheses of the most discordant kind. Most of these have been justly derided, and have past into oblivion. Some of them still continue to supply a spring of well deserved ridicule. It has happened, it must be confessed, in fewer instances, that they have inspired geologists with a cautious and diffident

---

dug up in many countries, have been often applied as evidence of the ancient existence of giants of the human species.

diffident opinion of their theories. Still, the investigations of this science have never stopt: KIRCHER has written largely upon it *; HOOKE imparted interest, by associating his notions of a central heat with the phænomena of earthquakes; the hypotheses of BURNETT, WOODWARD, and WHISTON followed; and, at the present day, it is interesting to reflect how completely these last three writers kept possession of a large share of the attention of the age which produced them. Their systems were overthrown, like that of BUFFON, by the observation of facts; and they were overthrown the more rapidly, in proportion to the imperfect nature of the data upon which they had been reared.

In the present day, when so many aids have been derived from the advance of the auxiliary sciences, and when facts have been increased so greatly, Geology, like other branches of

---

* In his *Mundus Subterraneus*.

of useful knowledge, has assumed a descriptive form. Its researches have guided the miner and the engineer. But how often have you lamented with me, that in our two prevailing theories, the same attempts are still made, as in the most ancient times, to reduce all the phænomena observed to one or two leading ideas. How often have we been surprised, when studying this subject, to find, that these leading principles could not be at all reconciled to a correspondence with our present knowledge. So rapid has been the progress of Geology, that it may be safely affirmed, that there is no person attached to this study who is at present a Wernerian or Huttonian, in the sense which, a few years since, was confined to these designations. The necessity of curbing or disregarding the influence of hypothesis has been fully seen; and the discovery of facts has gone on with a rapidity which the march of theory has been unable to overtake. No longer are the pretensions of Geology derided, or its researches deemed useless. To trace the nature and changes of the planet which he is destined to inhabit, must always be a sublime inquiry for Man. If all the objects sought cannot be yet attained, enough is known to impress us with the deepest interest. We know not, indeed, the history of the revolutions of the globe; we may never know them all; to accomplish this may be beyond the powers of the mind. But if we discover sea-shells in the rocks of high mountains, it becomes necessary to conclude, that, at some former period, these shells existed with living animals at the bottom of the ocean. If we find a rolled or rounded stone in the heart of a stratum, we must infer that it had once belonged to a rocky mass previously existing, and had been subjected to the process of wearing down, like the stones in the beds of our present streams. In the coal of our fires it has been satisfactorily shewn, that we burn the altered wood of a former state of the world. Many species of animals have perished, but have left their remains in the solid rocks, to attest that they had once existed.—The changes to which our world has been subjected are, in fact, too striking and too mighty, to be passed by unobserved.

served by the most uninformed eye. Every mountain has given a character to the lower lands around it; every valley bears marks of the action of water. When we penetrate the superficial strata, we are constantly impressed by appearances, which impart ideas of the action of general laws. When we carry our observations farther, a great regularity arises out of what at first sight appears an inextricable confusion. By the discoveries in the skies, and the accuracy with which the dimensions of our own and of other worlds have been measured, and their distances and specific gravities ascertained, we may be prompted to hopes of the most sanguine kind, from the careful and patient investigation of appearances which are daily within the reach of our unassisted senses. In the language of CUVIER, "genius and science have "thus burst the limits of space," and may yet impart to us some certain knowledge of our own globe. And after we are gratified with the scenery of the landscape, in traversing a country for the purpose of geological investigations, a higher pleasure arises from the elevation of the mind to new ideas of the great events to which the waters and the land have been subjected in remote ages. We find ourselves suddenly introduced to the display of infinite Wisdom and unbounded Power, exerted upon the largest masses of matter, and acting on the most extended theatre. The ruins of a former order of things spring up at every step; the beings of far distant times pass before us; and the mind is carried onwards, by an irresistible impulse, to the consideration of a state which preceded the present calm and harmony of the System.

It would be unnecessary to detail, at great length, the arguments by which the ideas of Hutton and Werner on the construction of the world, have been usually supported. To WERNER we owe the first extended attempts to connect the facts of Geology into a regular science, founded on observation and induction; to him we also owe numerous investigations of the most useful and interesting kind. He appears to have selected, with great propriety, the primary and secondary rocks as the chief objects of his researches; it is in them that the disturbances exist on the largest scale, and it is to them that most theorists have resorted, for the purpose of determining whether the changes which left them in their present state were effected by the agency of water or of fire. His disciples and followers speak constantly of a chemical solution of all the primary rocks in a liquid, and their subsequent crystallization from it; and they refer to the evidences of similarity presented by nature to the crystals of artificial solutions; to a supposed universality of deposit in a regular order around the globe; and to the occurrence of water in the strata. They connect these proofs with that original fluidity of our planet, which follows from its being an oblate spheriod, or at least approaching to that form.

They are opposed by the complete want of a solvent to act on substances so varied as the materials of the globe; by the effects of compression; but chiefly by the nature of the precipitations which must have taken place from their ancient sea. This universal water must have at one time deposited chemically crystalline rocks, and afterwards let fall only transition and mud-like strata, in which many vestiges of crystallization notwithstanding appear. For, in a formation descending *from above*, all the rocks must have been contained in the liquid at the same time. If we suppose that a disintegration of the strata took place as they were depositing, and supplied new materials to be again dissolved, this is one of the greatest obstacles to the hypothesis of Universal Formations. In fine, they are met by the inconsistency of their fluid dissolving stony substances, and yet leaving untouched the bones and shells of organic beings which they inclose *.

The Huttonian Theory arrests the imagination by grand and original views, and by providing for a constant succession of changes in the world. Nor can it be denied, that it has afforded happy explanations of many detached phænomena, and, in its progress, has given rise to much of the evidence which the science affords.

---

* The consolidating effects of water are still to be proved.

Dr. Hutton calls in the aid of heat, from the impossibility of finding any other solvent adequate to the effects produced; from the non-existence of water in those rocks which bear marks of fire; and from the irruptive power often visible in veins and dykes where the regular strata have been broken, dismembered, or changed, in consequence of the introduction of streams of liquid matter supposed to arise from below. He connects this principle with another, the gradual disintegration of the land, by causes which we see daily operating. The prolonged action of air and water, of rivers and currents, wears away the land gradually, and spreads it over the bottom of the ocean. There the central heat, acting upon it, consolidates the mass; hardens fine gravel into sandstone, clay into clay-slate, calcareous particles into limestones and marbles. As this change goes on under the incumbent pressure of the ocean, the results differ, in many cases, from those which would arise if the same heat acted in the air. Sir

JAMES HALL has shewn, in a course of admirably conducted experiments, how limestone and marble melt under pressure, by being enabled to retain their carbonic acid; and how, under similar pressure, vegetable and animal substances assume bituminous and coaly aspects.—In some spots, the action of the heat has been expended in evaporating the waters of the sea, leaving its rock-salt crowded with organic remains. But its chief agency is exerted in gradually elevating the strata, by the propulsion from below, of immense fused masses of granitic rocks. These, by their heat, soften, but do not melt completely, the superincumbent strata; they often project into their fissures part of their substance; and they impart to them every variety of inclination and disturbance. Other streams fill metallic veins, or give rise to the phænomena of basaltic dykes. Basaltic rocks are themselves lavas, whose eruptions have taken place beneath the sea. Granite is the newest formation of the fire; it bursts through all the other strata, appears to support them, and is the basis on which they all repose. In it, and the rocks next to it, no organic remains are found, because the heat in which it was melted, and they softened, banished every trace of them, if any had ever existed.—In the first and most active periods of the central fire, a few gigantic masses rise above the waves, and are rapidly disintegrated. The ocean receives their immense debris, and the continents and islands gradually emerge from its level. Many secondary and alluvial tracts are thus formed, in which the valleys, as in the primary districts, are scooped out by the large streams which at first roll in them. The ruins of the mountains thus form the low land of the new continents, and only parts of them remain, to attest what they once had been.

These changes continue to act, till the continents, thus formed, are again gradually returned to the ocean, and spread over its bottom. There the strata are again formed as before, and a new elevation of matter from the central regions again elevates them. Our present land has thus been formed from the decay of one which preceded it; and it is now itself furnishing the materials from which another will be raised. The land is the perpetual theatre of the decay of minerals; the ocean, of their renewal in new forms. The hypothesis of Hutton does not provide for one change only, but for many; as Nature has provided regular periods for all the disturbances which have hitherto been discovered in the Astronomical System.

Simple and grand as the Huttonian Theory appears in its outlines, and though it involves the action of both water and fire, yet the objections to it are too numerous and obvious to allow it to satisfy any reflecting mind. When we allow the existence of a central fire, and gratuitously suppose, that, though always present, it has only acted at certain times, when the force opposed to it was greatest, and acted most powerfully beneath the bed of the ocean, difficulties still crowd around us. Why did the heat act so gradually and regularly, as to melt granite and basalt, and only soften gneiss and mica-slate? How do soft beds often occur *under* the most consolidated rocks; as rocks of sandstone, for instance, resting on loose sand? The rise of the level of the ocean, in consequence of the spoils poured into it, is still to be shewn. The renovating powers which Nature has provided to balance the destroying energies which appear in her works, are entirely unnoticed. For many ages, before all the materials of the land were conveyed to the ocean, a world must remain without mountains or high lands, sufficient to arrest the descent of water in rain. But the causes which operate in preserving the mountains, have not been investigated.—In these and other respects, we can pay no tribute of applause to the Founder of the Huttonian Theory. He will never, assuredly, be ranked with BURNETT, who, incapable of perceiving the harmony and utility of the present system of the world, represented the mountains as the effects of the divine displeasure at the flood, and the antediluvian state of the Earth as owing many of its advantages to their total absence. But he can only be regarded as the framer of a system which explains but a part of the phænomena of the world.

Hutton supposed, and Sir James Hall confirmed, by numerous and decisive experiments, the effects of a great compressing force acting on mineral substances;—an inestimable advantage! always to be ranked among the happiest discoveries of Geological Science. The appearance of limestone possessed of all its carbonic acid gas, and of coal, with its volatile parts undissipated, find here complete explanations. Sir James Hall even formed crystallized limestones and marbles from chalk and other finely divided carbonates of lime *. The advantage of this truth, however, appears to be lost to the Huttonian Theory, by the fact already mentioned, of the occurrence of unconsolidated substances in the hard strata. Layers of fine sand are sometimes interposed between layers of mica or talc. —In another instance, some of the phænomena of agate-balls have been explained by Mr Playfair in a very satisfactory manner, from an ingenious

---

* Edin. Trans. 1805.

genious train of reasoning drawn from the appearances presented by the coats of which they consist*. Besides these, the principal facts in favour of the Huttonian hypothesis are, the impossibility of finding any other solvent than heat adequate to the effects produced; the phænomena of mineral veins filled from below; and the irruptive power displayed in them, and in dykes of granite and whinstone, where the regular strata have been broken, dismembered, or altered in their nature at the junctions, in consequence of the introduction of streams of matter ascending from below.

Some objections, still to be mentioned, apply equally to the Wernerian and Huttonian hypotheses, and shew us their complete fallacy as guides to a true system of science. In the Wernerian doctrines, the distinctions between primary, transition, and secondary rocks, are accounted for with great appearance of truth;

---

* Illustrations, &c. § 73, 74.

and the hypothesis of Universal Formations allows us to explain how the same rocks, accompanied by the same beds, minerals, and mode of stratification, occur in all parts of the globe yet examined; and how organic remains are present in some, and absent in others. To WERNER belongs the praise of having indeed first accurately distinguished the Mountain rocks. Many interesting facts with regard to their regular disposition, which he discovered, are disregarded by the Huttonians, who are not accustomed to subdivide the rocks as he has done *. But in the Wernerian System, the true distinction of rocks into conformable and unconformable, though well described, is not accounted for †. The Huttonians, on the other hand, while

---

* The Wernerian Divisions of rocks have, however, been of late certainly carried too far. M. Tondi, in 1813, enumerates 16 primary, 11 transition, and 57 Secondary strata, all principal, or *universal* formations.

† In quartz rock, we have one example of erroneous position in the Order of Werner in the Primary rocks; in the Secondary more have been found.

while their ideas explain the reason of unstratified lying under stratified rocks, afford no hints to explain why granite and gneiss, so near to each other in nature, are separated in their formation by intervals of time so momentous. They say nothing of the regular succession of the rocks commonly denominated Primary; nor do they assign any reason why gneiss should lie below mica-slate, and the latter below clay-slate or limestone strata. We are thus led to that fatal objection to the Huttonian hypothesis, which detects, at once, the fallacy of its foundations. In a long series of years, during which the whole of the land, or the greater part of it, is spreading out in fine particles over the bottom of the sea, the central heat is supposed to be acting upon it, and, after consolidating, to elevate it into new continents, which are again degraded in their turn. But when the spoils of the land have been spread over the general bed of the Ocean, how came the different substances to separate into strata? The strata which are exposed to our observation at present, are generally of uniform structure, and very often well

can

defined and distinct from each other. How can the substances which formed them have been separated at the bottom of the sea? A river rolls down mud and sand of all kinds, from all the strata over which it has passed in its course; and the bed of the ocean must be covered with this miscellaneous assemblage. What brought order and arrangement out of a mingled mass of particles of sand, clay, granite, slate, and other substances, and produced from them a series of strata of gneiss, mica-slate, and other rocks, all arranged in a determinate order, which is also related to the nature of their substance*? We see them distinct on the land;—How came they to separate? I am not aware that Mr Playfair has made one remark on this subject, which forms an insuperable objection to the principal postulate of the Huttonian Theory.

---

* Though heat can consolidate, it cannot form strata, for it would obliterate them in the formation. There is, indeed, no Huttonian hypothesis for the formation of strata and beds of well defined and distinct rocks, nor for the origin of strata of any kind. This theory, which cannot account for stratification, has no explanation of transitions, nor of alternations. If granite were erupted from below, and forced up an incumbent bed of rock, how does it graduate sometimes into gneiss?

I have only mentioned a few of the imperfections which attend these two theories of the earth *.

Both are entirely unsatisfactory in their first principles. It is the best praise of both, that many phænomena meet with happy explanations from them. As *true theories*, systems of knowledge resting upon facts, observations, and experiments, they are both decidedly imperfect in explaining the constitution of the globe; but as *hypotheses*, depending on assumed facts, they have been extremely useful, by prompting, with ardour, to the accumulation of knowledge. Had it not been for the Huttonian Theory, we should not have known the effects of heat acting under compression. Had it not been for the system of Werner, we should not have become so soon acquainted with that mass of facts which his disciples have brought forward from the most distant countries of the Globe. Both have thus extended the limits of true knowledge, and added new domains to the regions of conjecture. As observations accumulate, they can only rank among those ingenious speculations which have in all ages prevailed in the sciences, before the dawn of truth gradually arose. Let us recollect, too, that there are great difficulties to be overcome, in a problem so much involved in intricacy; and that the true constitution and history of the earth cannot be deduced from any series of facts of one kind, however extended, but from all that are known. I may be allowed to add, that, great as is the accumulation of facts at the present day, I still regard it as improper to affirm that they are sufficient to enable us to generalize them *all* into a true system of science, by the inductive process of Lord Bacon. At any rate, I shall endeavour not to conceal those objections with which I am acquainted.

---

* Other imperfections of both theories will occur afterwards. I might mention, here, the Independent formations of coal and flœtz trap, as among the best instances of *description* in the Wernerian Geognosy.

The first framers of theories of the Earth, were accustomed to go back to the original formation of matter. When we infer solely from observations, it is, however, by no means necessary to do this, and it may be even shewn to be somewhat improper. It may, however, be remarked, that, from the advance of knowledge, any theorist who wishes to go beyond the present arrangement, has great advantages over those of former times. The demonstrated possibility of all kinds of matter existing in the form of gas, and the most important elementary substances attached to our planet, being in fact airs when uncombined; the appearance of worlds in the skies in every state of formation, from a lucid nebulous cloud to a fixed or dense planet, surrounded by a regular atmosphere *; the phænomena of meteoric stones, and the existence of snow on Mars, allowing us to draw some

---

* See Herschell's observations on the Sidereal and Nebulous part of the Heavens. Philos. Trans. 1814, p. 248.

some inferences with regard to the nature of worlds far distant from our own; these and other circumstances are favourable to such speculations. But no theorist would now ascend to that æra when the solid, liquid, and aëriform constituents of the globe, formed an inflamed and resplendent star; or when the two airs, oxygen and hydrogen, which constitute the waters of our planet, were united by a flash, and condensed, giving out their heat to the surrounding mass to ignite it, or acting suddenly on its metallic nucleus. As well might we set free the chlorine of common salt, or unite, by the electrical spark, a great part of the constituents of our atmosphere into nitric acid, and employ these bodies as effective agents. Of a similar nature, in the present confined state of the obscurest of the sciences, are the inferences drawn from the magnetism of the globe, and its connexion in this respect with the other planets. Though speculations of this kind, founded on modern science, are far more certain than those of writers who have deranged the position of the globe in the solar system, altered the rate of its motion, projected it from the sun, or brought a comet to inflame or deluge it*; and though they supply us with new views of the great resources of nature; yet, if we could not infer legitimately from the appearances observed, that such phænomena had taken place, and if we could not apply them to the minute explanation of the facts before us, we should only wander in the dark, without any certain guide to an exact science.

---

* Burnett, Whiston, Buffon, and others.

AMONG the questions which it is most necessary to answer at the present day, before attempting a general theory of the appearances, are the following. Can we draw, from the *colour* and the *nature* of rocks, any exact inferences with regard to their origin? What is the connexion which exists between granite, and the rocks which are next to it in order of *position?* What are the relations which exist between unstratified granite and basalt, and the stratified rocks? What is the nature of all strata, as to a chemical or a mechanical mode of deposition? Where are the limits of these two kinds of deposit? Or, do any such limits exist? How can we account, in connexion with other appearances, for that general direction of the greater part of the strata, which is observed throughout the world?—These inquiries are of great interest in this science; and I shall, therefore, proceed to treat of the *colour*, the *nature*, and the *position* of rocks.

When we refer to the writings of both Wernerians and Huttonians for exact criterions, derived from the constitution of the rocks themselves, we find them extremely deficient in supplying such proofs as can satisfy the mind.

I have mentioned the explanation of agate-balls, as having been given by Dr Hutton, from the mode of arrangement which is seen in the different *coats* of which they consist. These, from the exterior ones always compressing the interior, must have consolidated from the circumference inwards, and therefore, by a simple fluidity, such as heat alone can produce *. The water, which is sometimes entangled in these nodules, as in rock-crystals, is accounted for by the compression to which, at their formation, they were subjected.

If we can extend such criterions, and render them sufficiently strict; if we draw them from the constitutions of the minerals themselves, some assistance will be rendered to this rising science, and, perhaps, new aids be afforded to the classification of rocks, which is still in so imperfect a state.

---

* Playfair's Illustrations, § 78.

The tests of an igneous or an aqueous origin have been sought for in various phænomena. In the rocks which are crystalline, the absence of water cannot be considered as any certain mark of igneous formation; for some watery solutions deposit crystals very nearly or altogether free from water. On the other hand, the presence of water in basalt and other rocks, cannot be regarded as any decisive proof, that they were not modified by heat; since water might be retained by them in two modes already known,—by a chemical affinity, which the heat could not overcome, or by a compressing force, which would prevent it from escaping in steam.

The imperfection of these reasonings led me, some time since, to consider, whether a more certain criterion of origin might not be derived from the presence of the metallic oxides, which impart colours to most of the primary rocks. Granite, the most important of all, is never free from colour in some of its ingredients. The quartz is generally colourless; sometimes possessing only slight shades of brown. The felspar is often red, and the mica and hornblende black, from the presence of iron. While a pure white felspar, as *Petuntse*, and a decomposed one, as *Kaolin*, yield no iron in their analyses, the other varieties of this mineral give from one to four *per cent.* of that metal[*]. The jade of

---

[*] Of the Felspars containing iron, adularia and the amazon variety from Siberia, yield least.

Adularia of sp. gr. 2.57, gave to Klaproth 68 of silex, 15 alumina, 0.5 iron, and 14.5 potash.

Vauquelin found no iron in one specimen which he examined.

Amazon stone, sp. gr. 2.70 gave 62.83 silex, 17.02 alumina, 3. lime, 16. potash.—*Vauquelin.*

Common Felspar from Piemont, 62.4 silex, 17 alumina, 1.2 lime, 4 iron.—*Vauquelin.*

Mr Chenevix found 2 *per cent.* of iron in felspar from the Carnatic.

The Labradore Felspar contains 3 and 4 *per cent.* of iron.
Allan's Tables, XLII.

Saussure yielded to Klaproth no less than 6.5 *per cent.* of iron*. In Mica, the proportion of iron is considerably increased; and to Klaproth and Vauquelin, this mineral yielded from 4½ to no less than 22 *per cent*†. Crystallized hornblende gave to Laugier no less than 22.69 of iron; and some varieties or subspecies, to other analysts from 9 to 35 *per cent.* Hyperstene or Labradore hornblende, yields 24.5 *per cent.*, and augite, a mineral nearly allied to hornblende, from 6 to 18.25 of the same metal.

From the abundance of iron in these substances, a proof may be drawn of the rocks in which

---

[*] To Saussure himself it gave 12.25 iron.

[†] Mica of Muscovy, Silex 48. Alumina 34.25, Magnesia .5, Iron 4.5, Potash 8.75, Water 1.25.—*Klaproth.*

Mica of Muscovy, Silex 50. Alumina 35. Lime 1.33, Magnesia 1.35, Iron 7.—*Vauquelin.*

Mica of Zinnwald, Silex 47, Alumina 20, Iron 15.5, Manganese 1.75, Potash 14.5.—*Klaproth.*

Black Mica from Siberia,...Silex, 42.5, Alumina 11.5, Magnesia 9, Iron 22, Manganese 2, Potash 10, Water 1.—*Klaproth.*

Allan's Tables, LXXI.

which they occur not having been precipitated from a state of chemical solution in any liquid. For, if the quartz, mica, and felspar of granite, were dissolved in a fluid, why did not the oxide of iron, also a constituent, diffuse itself equally throughout the substance of all the ingredients? Why should it attach itself only to the mica, felspar, and hornblende, and leave the quartz colourless, as we see it in most granites? In this case, no satisfactory reason can be shewn, why the quartz should not have received a share of the iron. If it be said, that the iron oxide had no chemical affinity, tending to combine it with the quartz, this would be met by the remark, that in many situations quartz is impregnated with iron in the most varied proportions.

Granites sometimes occur with two kinds of felspar, one of a reddish, and the other of a lighter or whitish aspect, both being equally disseminated through the substance of the stone. Such is the case in several specimens which I have collected, and in others which I have seen described *. In other examples, part of the fragmented crystals of the felspar is tinged of a deeper red than the rest. Here it may be inquired, why, on the hypothesis of solution in a liquid, one part of the felspar should receive iron, and the other little or none?—So in greenstone, whin, and other rocks of the Trap suite, which consist of Felspar united to Hornblende or Augite, how often is the felspar destitute of that colouring principle of which the hornblende and augite contain so much. To Porphyry, and to the limestones which enclose hornblende, the same remark will apply.

On the other hand, if we suppose the agency of heat, there are not wanting proofs to shew, that these appearances coincide exactly with

---

* There is a quarry to the North of Peterhead, with a granite of felspar of two colours. Containing hornblende, it would be called a Syenite by the Wernerians.

Granite with greenish-white felspar, sometimes traversed by finer grained, in which the felspar is reddish-white, is described by Karsten, (Leskean Museum Catalogue, p. 374.)

A granite with milk-white felspar, spotted with red, occurs in a celebrated quarry ten versts from St Petersburg.—Ib. 374.

with what we may legitimately infer as the effects of that power.

In the scoriæ of furnaces, there are always present substances which receive a tinge from iron; and in particular, in many of those of glass-houses, the glass in the bottom of the pots passes, as is well known, by long continued fusion, and subsequent slow cooling, into masses of greater or less opacity, resembling in some cases what is called Reaumur's porcelain; in others approaching to the general aspect of a trap rock.

In inspecting many specimens of this kind, I have always been struck by the separation of colours in the mass; a separation generally pretty distinct, often perfectly so. One part is tinged yellow or green by the metallic oxides, another is left of a pure white.

In the lighter scoriæ or slags of iron-furnaces and lime-kilns, the same appearances are seen, often affording the happiest examples of the effects of long continued fusion in separating colours from each other, frequently by exact boundaries.

In all preparations of *pastes*, or artificial gems, the difficulty is, to secure the equal diffusion of colour through the glass. Hence those who prepare them, find it often necessary to cool them rapidly, and fuse them repeatedly, from the tendency of the colours given by the metallic oxides to separate. A long-continued fusion introduces a great disturbance into the results, and is very unfavourable to the uniform distribution of hue. Hence the necessity of forming *frits*, and of cooling the glasses obtained in some stages of the process, in cold water *. The effect of heat is, indeed, in all cases, to separate colours.

Few experiments have been made on the fusion of granite. While the felspar and mica melt into glasses or slags, the quartz resists the heat, and is left untinged by the colours of the surrounding materials. Mica fuses easily in the focus of a powerful lens; and, on cooling, exhibits changes of colour, probably from a change in the constitution of its oxide of iron.

---

* M. Fontanieu describes the mode of preparing artificial gems. The colourless Mayence and other bases are obtained by melting thrice, and each time pouring into cold water.—See Edin. Encyclop. x. p. 128.

The conclusion is obvious. The quartz may escape, or may never have received the tinge which the felspar and mica possess. Calcareous spar may be left unchanged in the vicinity of mica-slate, hornblende, or basalt. When two kinds of felspar occur in a granite, the inference may not be so immediately obvious, and several opinions may be hazarded. The granite may have been recomposed from materials previously existing, of which the crystals of felspar were distinguished, by possessing various impregnations of iron. Or there may exist, in other respects, as well as in colour, an essential difference in the constitution of the two varieties of felspar, which form the mass of the stone. I rather think it, however, more probable to suppose, that, in such cases, the duration of the periods of cooling will afford the most simple explanation. The same change may not have taken place in the felspars, which a more prolonged cooling would have effected, And as we cannot suppose that the action of heat is in all cases a perfectly uniform force on large masses of matter, this circumstance, while it explains the above appearances, corroborates the explanation, and accounts for the reason why quartz is itself, in some cases, tinged slightly with metallic hues, and why a gradation of colour is sometimes seen in the felspars of many granites.

It may be remarked, that the new ideas which BERZELIUS has given of the constitution of the mineral species, militate against the above details. This excellent chemist has shewn, that an examination of the analyses of many minerals, exhibits the combination of their elements in definite proportions*. He has traced a pretty exact correspondence between some of the natural combinations of silex and oxide of iron, and the known proportions in which these substances unite, and has founded a new system of Mineralogy on this principle. As these siliciates of iron occur in such abundance, as in mica, asbestus, tremolite, chlorite, tourmaline, prehnite, and other minerals, it may be inferred, that, in all cases, the combinations of iron are made in this mode. This inference Berzelius himself has not drawn; and he remarks[*], that, in the present state of chemical analyses, it is altogether impossible to calculate the composition of a mineral containing iron, with any degree of certainty. The principal difficulty arises from the degree of oxidation in which the iron exists in the stone, which the most expert analysts have hitherto failed in ascertaining perfectly[†]. Till the chemical analysis of minerals is brought nearer to perfection than it is at the present day, we are therefore warranted in inferring, from the appearance of iron in all possible proportions, that no part of our present knowledge of the constitution of minerals, is hostile to the theory of their origin, which has been deduced from the colour of rocks. The principles of Berzelius only apply to those cases where the iron is present in large or in considerable quantity. If the presence of the smallest quantity or trace of iron be supposed to involve the idea of a definite combination, this circumstance lends no aid either to the aqueous or the igneous origin of minerals. But if the distribution of iron be in small quantities, and at the same time not uniformly spread through the mass of the mineral, we can only resort for an explanation to an origin from heat. It is probable, that the farther examination of minerals with regard to this interesting subject, will be productive of useful discoveries.

---

* "Attempt to establish a pure scientific System of Mineralogy by the application of the Electro-chemical Theory and the Chemical Proportions," 1814......Berzelius considers silica as an acid with great probability, p. 28......His principle is unfolded in p. 50, and constitutes a great step in the knowledge of the nature of minerals, should it be established fully by experiments, which at present it has not been.

---

[*] Attempt, p. 80.

[†] Ibid. p. 81, 82.

The phænomena of dykes of whin and granite, will supply us with a farther proof with regard to the truth of the above deduction. Though I have examined many of the dykes of Scotland, and almost the whole of those of the

County of Antrim, I was first most sensible of the appearances I allude to, in some granite veins on the rocky shore of Kincardineshire, a few miles to the south of Aberdeen. At the fishing-town of Findon, and for some miles on both sides of it, the rocks, which are chiefly gneiss of large-grained varieties, are penetrated by veins of granite, consisting of white quartz and flesh-coloured felspar. Where the gneiss passes into mica-slate and hornblende-slate, as at a spot denominated The Cove, there is a good example of a wide vein of granite passing through the slaty rock, and producing near the junctions a variety of colours in the shistus, and a far greater thinness and tendency to division in its strata, than are seen in the same rock at the distance of a few feet; the strata, indeed, near the junction, becoming as thin as paper. At a spot about two miles to the northward of this last place, there is a remarkable dyke of trap, which traverses the gneiss, in a direction nearly north and south, and with a breadth of about 25 feet. The part of it exposed on the cliffs, is from 70 to 90 feet in height, and in length about 300 yards, for the greater part of which, being laid bare by the waves, every facility is afforded for examining the junctions which it forms with the gneiss, on both sides of its course. It is a well defined greenstone of felspar and hornblende, sometimes offering minute crystals of calcareous spar and sulphuret of lead. In the middle, and at some distance from both sides, the rock is distinctly pretty large grained; as the contact with the gneiss is approached, the grain becomes finer, till it passes into a rock of nearly homogeneous texture. At the same time its colour is changed from a dark olive green to a hair brown; it has become, too, far harder, and of a splintery fracture; and in many places a radiation of light brown colours appears in it, exactly such as we would expect from the action of heat. The difference of hardness is still more sensible, when we notice the facility with which the interior part of the dyke decomposes, and the obstinacy with which the sides, though beat by the waves, resist all change; and when we observe the small size of the fissures into which the rock divides at its junctions, and contrast them with the largeness of the blocks which constitute the mass of the unstratified trap. The decomposing and more central blocks, falling to sand by the action of air and water, exhibit, as is usual in this rock, a concentric structure, exactly like the coats of an onion.—Here the inference from colour is obvious; and would be alone satisfactory of the igneous origin of this dyke. But when that conclusion has been confirmed by every thing which has been observed in many other dykes, and when the gneiss has in this case, from its previous consolidation, undergone no change, additional proofs are added.—On the hypothesis of solution in a liquid, we are completely deprived of the assistance which these facts give to our reasonings, and we have no explanation of the appearances themselves; while it is not easy to conceive how substances, so compound as granite and trap, could have been precipitated chemically so blended as we see them, and yet so perfectly distinct in their colours. On the other explanation, these difficulties disappear.

I proceed to another view of the origin of rocks, deduced from their *nature* and *position*.

I have been led to this investigation, in consequence of finding no satisfactory answer in any of our theories to the following questions. What relations exist between granite, an unconformable and unstratified rock, and the rocks which lie immediately above, as determined by Werner and other geologists? Why should Gneiss*, where it occurs, be always the rock next to granite, if, on the Huttonian hypothesis, that granite was elevated from the ocean, raising up the strata before it? Granite can have, apparently, no more relation to gneiss than to any other rock in the series.

---

* Gneiss, or slaty granite, is constituted of the same materials with granite, arranged in a slaty form.

I am obliged here, as in other places, to use the names of *Primary*, *Secondary*, &c. though not strictly accurate. But I have no choice, there being in fact no nomenclature yet in Geology, which does not involve an hypothesis. The Wernerian terms having acquired the most general currency in Europe, they are used here, as *names* only, without believing in the theory which these names in some cases express. Where granite is mentioned, it is always to be understood as unstratified, or as granite in *the mass*, not *in beds*; unless the contrary be mentioned.

On the Wernerian supposition, on the other hand, that granite fell down first from the universal dissolving liquid, what relation has it to gneiss, that the latter should constantly succeed it?

Of the unstratified rocks, GRANITE is by far the principal, reckoning under this appellation all compound aggregated rocks, where felspar, the chief ingredient in most cases, is united to various portions of quartz, mica, and hornblende, or to one or more of these minerals. Garnet, tinstone, and shorl, are often imbedded in its substance. The name of Syenite, from Syene in Upper Egypt, has bsen given to granites containing hornblende, instead of mica; and many, though not all Wernerians, besides denying that hornblende was contained in any true granite *, have

---

* "Not a trace of hornblende has hitherto been discovered in granite."—Jameson, Geognosy, 1808, p. 113.

This

have attempted to assign to unstratified Syenites, in all cases a very different order in the system

---

This assertion will apply to no primary mountain of granite in Scotland, for most of ours either contain hornblende instead of mica, or traces of it and chlorite. Many observations have shewn that it applies to very few of the granites of the Continent. See Mr Kidd's Observations, where the subject is examined at length. Saussure found the place of mica supplied by chlorite in the granite of the top of Mont Blanc, (§ 204.) The question here has been much narrowed, and may now be stated thus: Shall we consider no rock as granite, which contains hornblende, however primary be its position? Or, shall we say, that all such granites, and the strata above them, belong to the second, the third, or the fourth formation, or to transition formations?——Dr MacCulloch, (Geol. Trans. II. 420.) has proposed, with great propriety, to give the name of Granite to all rocks of felspar, quartz, mica, hornblende, or chlorite, if the felspar be abundant; and to confine the term *syenite* to aggregates of hornblende and felspar which are not greenstones, and are associated with traps.

The Granite Veins near Bunawe in Argyleshire, are described by Dr MacCulloch (Geol. Trans. vol. IV. 120.) as consisting both of granite and syenite, both evidently coexistent, and both ramifying similarly through the shistus, contorting tem of Universal Formations, from that which granite occupies.—Felspar is the principal constituent of almost all granites, and is, indeed, by far the most widely disseminated mineral in the world. It is the constituent most subject to decomposition, from the potash and iron which it contains; while quartz is the most indestructible.

No person can view a primary country without being struck by the difference which appears, when, leaving mountains or precipices of pure granite, he observes the first rock which lies above it, and which is often gneiss. I shall not say much on the celebrated controversy of the stratification of granite. I believe that it is now generally acknowledged, that in the great mountain masses, it is unstratified; or at least, that if it be stratified, its stratification is of a nature

---

contorting it, and having fragments of it within their substance. This is a complete proof, if more were wanted, of the geological identity of two rocks so improperly separated by Werner, by the accidental presence or absence of the single ingredient hornblende.

ture very different from that of the rocks which lie above it. The largest masses, which compose the central parts of the highest mountains in the old world, are at any rate of the latter kind. In the discussion into which I am about to enter, I hope to be able to shew, that granite occurring regularly stratified in some situations, is not inconsistent with the principles which I am about to state.

I ought not, at the same time, to conceal from you, that I was long of opinion that granite offered a pretty regular and vertical stratification in many places, though I could never confound this appearance with that of the great regularity of the other strata. The aspect of some extensive quarries and precipices of pure granite, which I saw for the first time in 1812, appeared to have strong marks of regular stratification. Several subsequent visits to the same spots, and indeed to almost every granite precipice in Scotland, altered my opinion slowly, and have shewn me, that there is very little of regularity in the arrangement of granite in the mountain mass; and that the fissures whence the idea of strata has arisen, are simple rents, not completely continuous, and not always closely related at their junctions with each other *. They divide the granite into blocks of larger or smaller size, which decompose in concentric layers, as

---

* On the mountain *Lochnagar*, where the granite precipice is a mile and a half long, and from 300 to 1500 feet in height, the appearance of large vertical plates is in many spots distinct, particularly when viewed from the lake at the bottom of the cliff, or when ascending in the steep ravines. The narrow and extremely deep fissures exhibit a great inequality in the hardness of the rock. Other precipices, frequently examined, are those of Ben An, Ben a Bourd, Ben Chaoirn, Carngorm, (particularly around Loch An, the most savage and solitary spot in the Highlands of Scotland), Ben Macdhui, Breriach, and Carntoul, the last two offering extensive and very grand precipices, and *choires* or basins, in Glen Garchary. These mountains, with Ben Vrotan, Ben Main, and others, constitute the central land of the island, and since 1810, have been accurately measured. Ben Macdhui is 4300 feet, approaching nearly to Ben Nevis, and several of the rest are above 4000. Their positions are irregular with regard to each other; and the whole cluster must be regarded as the most primary tract in Great Britain.

as Dr MacCulloch has so well described[*]. How often similar rents have been mistaken for the marks of regular strata, is well known to Geologists. Thus, in a paper by Colonel Imrie[†], the rock of a large-grained conglomerate in Kincardineshire, the same which continues to skirt the Grampians on their eastern side throughout their course to the S. W., is described as stratified vertically. In the whole line of this conglomerate, at Stonehaven, the Burn, Callender, Oban, and other places, I never could perceive one vestige of stratification in vertical masses; but only rents, vertical, and often dividing the pebbles of jasper or quartz so far from each other, as to shew the extent of the slips. On the sea-coast, some miles to the south of Stonehaven, this conglomerate is seen resting on strata nearly horizontal; as Colonel Imrie has himself described *.

---

[*] Saussure has lamented the use of the term Vertical beds and layers, as applied to Granite, and he seems to have been the first who described granite decomposing in concentric layers. Jameson noticed it on Ben-echleven in Arran, (Mineral. of Scottish Isles, I. 42.)......See the excellent observations on the stratification of Granite, by Dr MacCulloch, vol. ii. p. 427.

Ramond, in his *Voyages au Mont Perdu*, has described accidental splittings of granite as crystalline forms, according to Dr Berger, who visited all Saussure's stratified places, Les Aiguilles of Chamouni, &c. and found all unstratified, (Geol. Trans. I. 150.)

At Aberdeen, the workmen call the good granite *post*, and the bad *drys*. The former is always a concretion in the latter, and often of great size.

[†] Wern. Trans. I. 455.

At any rate, Gneiss, the next rock to Granite, is often very different from it in aspect, though it consists of the same materials, quartz, felspar, and mica. It is always regularly stratified, and in most cases this is the only certain mark by which, in hand specimens, it can be distinguished from granite. It has every variety of size of grain, from the largest to the smallest, and in this respect it passes into granite by insensible gradations, though always different in aspect, from its being a stratified rock. It generally

---

* Wern. Trans. I. 457.

nerally contains more mica than granite, and less felspar; but the latter mineral still predominates in its constitution. All the varieties of its structure from the large grained to the fine slaty, are produced by the varying proportion of its ingredients; for we constantly find, that the largest grained with most felspar is deposited in the thickest beds; the smallest grained with most mica, in the thinnest layers.

Gneiss, or Slaty Granite as it has been also called, passes by insensible gradations into quartz rock, the felspar and mica both disappearing. Werner has indeed placed quartz rock above porphyry, and does not seem to have paid much attention to it. It has been noticed extensively by several writers, and as one of the chief primary strata, it has been much studied, particularly by *Dr MacCulloch* *. It consists of quartz, either perfectly crystalline in aspect, or passing into every variety of granular

---

* Saussure (§ 999.) describes rocks of a fine granular quartz, arranged in rhomboidal leaves. Kirwan (p. 208. Geol. Essays) allows that sandstones, without organic remains, should be ranked among primary rocks. Dr Townson (Travels in Hungary) observed strata of granular quartz (which

---

(which he calls primitive sandstone) lying upon granite, in all states, from fine granulated to that of breccia.....See also Kirwan, Geol. Ess. 179.....Playfair's Illustrations, p. 22. 171. &c....Jameson (Min. of Scottish Isles, I. 170.) has described the alternation of granular quartz rock with mica-slate in Jura, and thinks it subordinate to mica-slate: he mentions having seen it *below* mica-slate....See also Wern. Tr. vol. I. p. 117....He is now inclined to believe in the *chemical formation* of sandstone, and such conglomerates as the rolled rocks and fragments of all kinds at Cartland Crags, (Wern. Tr. vol. II. 499.); and his words in p. 625. of the same volume are,—

" Rocks having the same structure and general appear-" ance as red sandstone, appear occasionally in transition, " and also in primitive districts, as in countries abounding " in clay-slate and gneiss, a fact which at first sight ap-" pears inconsistent with the general distribution and ar-" rangement of the different rock formations."

Humboldt (Tableau de Physique, 128.) states, that in South America, quartz constitutes exclusively a mass of more than 9500 feet in thickness.

Dr MacCulloch has observed and written extensively on quartz rock. He thinks Isla the best place to determine its true lar appearance, from the finest grain, till the whole rock assumes the structure of a sandstone, and

---

true position, (Geol. Trans. II. 413.) In Jura, (p. 455.) he found the beds of it coarser in texture at the bottom than at the top of the mountains. He has traced a complete gradation from the most crystalline and compact kind, to a rock with rounded pebbles of quartz inclosed, (vol. II. 455.; vol. IV. 267. &c.) Hence he infers a structure of it, partly chemical, partly mechanical. What felspar it contains, being partly worn, supposes a recomposed structure, (II. 460.)

In Assynt, Sutherlandshire, he found abundant proofs of its resemblance to sandstone. In Sky, (vol. III. 30.) as at Balahulish, its surface is often varnished with a siliceous enamel. Its strata in Sky are often bent and fractured: he traces it often passing into a complete sandstone, alternating with the marble and shell limestone of that island, of which the great masses are constituted of syenite and trap, (Ib. 48.) In Ben Gloe, it is contorted like mica-slate. It passes into granite, (vol. IV. 270.)

My own observations on this important rock, so widely distributed in Scotland, commenced in 1812, in Mar. I was misled at first by the idea that it was a fine-grained gneiss, and paid little attention to it. It there forms several hills; and in that year, I had large specimens of it from Invercauld, convoluted in minute doublings. I observed its and sometimes of a conglomerate. Hence the resemblance which many varieties of it have to sandstone, and the name of Primary Sandstone given to it by several writers. Its place may be regarded as being well determined, both from observations, and from the fact, that quartz gradually increases in the finer slaty kinds of gneiss; and on the other hand diminishes in the smallest grained mica-slate.

Mica-

---

its passage into gneiss, in several spots around Mar Lodge. Dr MacCulloch's paper, published in 1814, established its interest. Having found in 1812 many rounded nodules in the mica-slate at the Linn of Dee, and been led to trace extensively the mechanical appearances in all the strata, I found many in quartz rock. In a journey in 1816 around Ben Gloe, I found many varieties of its appearance, in connection with mica-slate. On the western side of Carntoul mountain, I found it in 1813 lying above the unstratified granite, in conformable strata. It is always in that country nearer to the granite than mica-slate, as in Glen Dee, on the Ben Vrotan side. Hence, with Dr MacCulloch, I have inferred its position. His researches, on a rock which occupies so large a part of the Highlands of Scotland, are in the highest degree interesting. He has certainly established, that its outgoings are not so low as those of the mica-slate of that country, (vol. IV. 267.)

Mica-slate, or Micaceous Shistus, consists of mica and quartz. It is always distinctly stratified, and always slaty in its structure. The quartz diminishes, and the mica increases in its structure, as it becomes more finely slaty *. It is the rock which presents the greatest quantity of undulated or waved bendings. Garnet, hornblende, shorl, and iron-pyrites are its most common inclosures.

Mica-slate, is intimately connected with the next rock of the series, Clay-slate, always of simple structure, regularly stratified, and often inclosing variable quantities of mica, and crystals of iron-pyrites.

Primary Limestone follows. Its texture is granular and crystalline. It is stratified in beds of greater or less thickness, which are often found occurring in gneiss, and mica-slate, &c. It constitutes considerable tracts in some countries.

Primary trap, when connected with these rocks, is always in strata, and is divided into granular,

---

* Jameson's Geognosy, p. 119.

granular, and slaty hornblende rock, when it consists chiefly of hornblende; or into greenstone and greenstone-slate, when it contains felspar; and, besides these, hornblende is also found mixed with mica.

The other primary rocks, with the exception of Porphyry, are of less importance, being of rarer occurrence, and only forming small tracts. They are Serpentine, Flinty-slate, Gypsum, and Topaz-rock. Why the last was introduced as an universal formation, or distinguished from gneiss, to which it is related, does not appear. It is only found in one hill in Germany.

Porphyry is one of the most extensive rocks in distribution; it is also one of those which have been least studied hitherto. All the other primary rocks, excepting it and granite, are stratified: Porphyry is unstratified; and is thus connected with granite and unstratified trap *.

The

---

* The numerous varieties of this rock have been much neglected, as well as its transitions.

The nature of Porphyry is to have a basis, in which imbedded crystals, or parts of crystals, appear. The basis may be any substance of a fine grain, as clay, of various induration, or clay-stone, horn-stone, and often compact felspar, and pitch-stone. Felspar is the most common imbedded substance; but quartz is frequent. These are sometimes perfectly crystallized, sometimes rounded or irregular fragments. In some porphyries, there are balls of chalcedony, and other mechanical appearances *.

The position of porphyry is as various as its aspect. It is found in primary and secondary tracts. In primary country, it often rests immediately on granite, and is then hardest.

---

* As in the ancient *verd antique* variety. The Swedish porphyry contains red and green nodules. Saussure (§ 1289.) mentions a porphyry with spots of white felspar, sometimes rhomboidal and sometimes circular; such are common in Glen Shee. In those of Dauria, Patrin mentions spots of green and white, surrounded often by two zones of these colours. Saussure (§ 1578.) mentions globules of lime in a porphyry.

est [*]. In other cases, veins proceeding from it, traverse the granite and other strata; and, in this respect, associates it with unstratified trap [†]. Jasper, which is a hardened clay, is also related to it.

Gneiss sometimes assumes a porphyritic aspect, and so does granite. A transition from granite to granitic porphyry has been traced by Saussure.

---

[*] As on the mountain Benochie, in Aberdeenshire, where a mass of porphyry, of the hardest clay basis, inclosing quartz, lies unstratified, upon unstratified red granite. This porphyry offers numerous druses of quartz crystals.

[†] Porphyry veins in the killas (grey-wacke) rocks of St Agnes in Cornwall, are described in Geol. Tr. IV. 402. They are from half an inch to forty feet wide. By far the most interesting account of veins of porphyry, is in Dr MacCulloch's account of the mountain Cruachan in Argyleshire. They traverse the granite and shistus, and are from three to fifty feet wide, or more: they are well defined, and do not produce disturbances in the rocks which they pass through. They pass into basalt, of which veins occur in the same place, (vol. IV. 121.)

Saussure *. As it is unstratified, and has been found in the same mountain, associated with basalt and granite, it appears to be related in position to them. It has, however, been hitherto too little studied to allow us to draw from it many conclusions †.

Such

---

* Voyages dans les Alpes, § 155. At the Pass of Leney, near Callender, Dr Macknight mentions an example of mica-slate becoming porphyritic, and very hard, (Wern. Trans. I. 284.)

I have been twice on Ben Nevis, where the porphyritic rock of the adjoining district of Glencoe forms an enormous mass, resting on a syenitic granite. No stratification appears in either rock: the syenite is of pretty constant character; the other varied in every mode, as in Glencoe. Dr Macknight (Wern. Trans. I. 312.) has traced beds of mica-slate and gneiss below. All my observations went to connect the whole country with unstratified trap, to which the relations are numerous.

† I have here, with the exception of quartz rock, assumed the Wernerian order of rocks as true, because it agrees well with observations in many countries, but not in all. Cuvier has acknowledged, that no observations have made the order of all rocks correspond to the descriptions

of

Such is the order and general nature of the Primary rocks. With regard to these, I have already mentioned the first questions, of which I shall attempt the solution, the relations which they bear to granite, which is unconformable with regard to them, and unstratified.

The Huttonian debris, spread over the bottom of the ocean, has never been shewn to have any other characters than that of an uniform substance, such as adheres to the lead of the mariner. If it separated there into strata, like those which we see on the earth, why was gneiss

---

of Werner. Von Buch found well characterised granites lying over rocks containing petrifactions, in Norway. (See Analysis of the labours of the Institute, Thomson's Annals, x. 142. and Thomson's Chemistry, 1817, III. 559.) Raumer lately examined the Riesengebirge mountains, and for the arrangement of Werner, substitutes, 1. Granite, which is central; 2. Gneiss and Granite; 3. Green-slate; 4. Gneiss; 5. Mica-slate; 6. Clay-slate: (Thomson's Annals, VII. 478.) —all the last five being in the mantle-shaped position around the granite.

gneiss the first, mica-slate the second stratum, and so on?

At the same time, all the stratified rocks bear marks of having been formed by the agency of water; the very existence of strata shews this, and their regularity and parallelism throughout extended tracts of country, confirm it. It follows, that all the stratified rocks must have been originally soft, either from precipitation in a liquid in which they were *chemically dissolved*, or from deposition from a fluid, in which they were *mechanically suspended*. All theories admit one or other of these conclusions.

We may go farther, and infer that all the rocks, stratified and unstratified, exhibit evidences of the minerals which compose them, having existed as the constituents of other rocks, which had been altered or destroyed in order to form them. For granite, for instance, is composed of fragments of crystals of quartz, felspar, and mica; and so of others. This conclusion, however, it is not, in the present stage of our inquiry, necessary to consider.

It may tend to bring us nearer to a true result, if the questions, which are, at the present day, of highest importance in Geology, be stated, before detailing the facts from which their explanation may be deduced.

Why is granite always unconformable to the rocks below it, and they, when stratified, always conformable to it?

Why are the strata of gneiss, mica-slate, and clay-slate on granitic mountains, usually mantle-shaped?

What cause can be assigned for the uniform order in which gneiss, mica-slate, and the other primary rocks, rest on granite?

Why does gneiss generally contain more mica than granite, and mica-slate more than gneiss, and clay-slate less * ?

How can we explain the facts, that the largest grained gneiss is always the oldest or nearest to granite, and the finer and more slaty varieties farthest from it, or newest † ?

Or

---

* Jameson, Geognosy, p. 114.

† Ib. p. 115.

Or account for the same facts with regard to mica-slate, the large granular being always the oldest, and the fine slaty the newest[*]?

Why in clay-slate does the quantity of mica always diminish in the strata farthest from mica-slate, and is least in the newest strata[†]?

Why are the outgoings of gneiss strata always lower than the granite on which they rest, and higher than those of the mica-slate, which usually covers them[‡]?

Why are the outgoings of mica-slate strata lower than those of the gneiss, on which they rest, and higher than those of the clay-slate which usually covers them[§]?

Why does quartz rock frequently possess marks of a mechanical structure, and connect with sandstone, which is evidently an aggregate of rolled grains[||]?

---

[*] Jameson's Geognosy, p. 119.

[†] Ib. p. 122.

[‡] Ib. p. 116.

[§] Ib. p. 119.

[||] See *above*, p. 57.

Whence arise the very general bendings of gneiss and mica-slate strata?

How can we account for the constant transitions or passages of gneiss, mica-slate, clay-slate, quartz-rock, &c. into each other?

Or for the frequent alternations which strata of these rocks always present?

Why are thin strata so often connected with thick beds?

Why are strata of unconsolidated substances found in the midst of the best consolidated strata?

What reason can be assigned for the general direction of the strata of many countries from N. E. to S. W.?

1. Granite * is always unconformable to the rocks above it, because its mode of formation has been different from theirs.

This may be inferred from the following facts:

---

* It is always *unstratified* granite, or the granite in *distinct concretions* of Werner, which is here meant.

It is unstratified, while they are stratified.

It is found in the highest and lowest situations, in the countries where it occurs.

In mountains containing it, it is always the central or conical mass, as the precipices shew; the stratified rocks of gneiss, mica-slate, &c. being wrapped around it, in mantle-shaped strata, which conform themselves to its position *.

Like trap, it interferes with all the stratified rocks; for most of them have been found resting upon it †?

Veins of granite shoot upwards from the substance of its mass into the incumbent strata above them, disrupting them, and presenting appearances frequently described ‡. But similar veins from the gneiss, limestone, or mica-slate,

---

* The descriptions of the Hartz, and the Saxon mountains, in Jameson's Geognosy, p. 71. afford fine illustrations of this appearance.

† Porphyry, grey-wacke, limestone, and other secondary rocks, have been now often observed resting on granite.

‡ First by Dr Hutton in Arran and Glen Tilt.

slate, resting on granite, never shoot down into it.

Its *structure* is entirely different from that of any regularly stratified rock. Werner has described it with great accuracy*. It is formed into large globular distinct concretions, from one to two or more fathoms in diameter. These concretions are again composed of curved lamellar concretions, and always include a harder central mass. The spaces between these globular concretions are filled with granite possessing less solidity, and which decays rapidly, and thus leaves the harder central masses heaped on each other, or strewed about.

Dr MacCulloch has traced the structure of granite more minutely, from the appearances which it presents when decomposing†. The cubic and prismatic masses into which it separates, have their angles gently rounded by weathering; a curvilinear outline gradually appears,

---

* Professor Jameson's Geognosy, p. 105.

† See Observations on the Granite Tors in Cornwall, Geol. Trans. vol. II. 71.

pears, and more or less of a spheroidal form is at length developed. It must therefore be inferred, that the granite is unequally hard throughout its mass, from the centre to the circumference, and that a spherical form is its original structure. Nodules of spherical granite occur in Arran; and a particular variety, where the quartz, felspar, and hornblende, are arranged in a radiated and concentric structure, is found in Corsica *.

It will be afterwards found, that this form is the same with that assumed by basalt and trap rocks †, and that it is the form given by nature to all unstratified rocks.

No

---

* This remarkable rock, not discovered *in situ* till 1809, is described below under Basalt, where this subject is resumed. See also Pinkerton's Petralogy, vol. II. p. 612.—624. An orbicular porphyry is also found in Corsica.

In the variety called *tyger granite,* the hornblende forms radiating spheres.

† See the structure of greenstone in weathering, by Dr MacCulloch, in Geol. Trans. II. 398.

See below, under the *structure* of Trap.

No stratified rock assumes this structure; and the nature of *stratification* is completely opposed to it. Hence an original difference of formation between stratified and unstratified rocks may be legitimately deduced.

We have here inferred nothing with regard to the *nature* of the origin of granite.

2. A constant relation between the materials of granite, and those of the stratified rocks above it, is found to exist.

For instance, gneiss consists of felspar, quartz, and mica, and differs from granite only in being stratified. Mica-slate contains mica and quartz. Quartz rock contains the quartz of granite. For clay-slate, I shall refer to the best analyses of that rock; for when the fineness of grain and structure do not allow us to employ the external characters of the simple minerals which constitute a rock, a knowledge of its chemical nature may assist us*. We must not, however, rest upon this proof alone; for the relations of clay-slate to felspar have been traced by JAMESON, who has remarked the close alliance of clay-slate and compact felspar in geognostic position*. When we find, therefore,

---

* **Analysis of Clay-slate,......Silex 48.6, Alumina 23.5, Magnesia 1.6, Peroxide of Iron 11.3, Potash 4.7, Water and**

---

and Volatile Matter 7.6, Traces of Carbon and Sulphur. —*Daubuisson*, who endeavoured to shew, by this analysis, that mica-slate and clay-slate are only different modes of combination of the same elements. See Journal de Physique, 1809.

Compact Felspar of Salberg in Sweden,......Silica 68. Alumina 19. Lime 1. Potash 5.5, Oxide of Iron 4. Water 2.5. —(Godon de St Memin, Jam. Min. I. 380.)

Compact Felspar of the Pentlands,......Silica 71.17, Alumina 13.60, Lime 0.40, Potash 3.19, Oxide of Iron 1.40, Manganese a Trace, Volatile matter 350.—(Dr Mackenzie, Wern. Trans. vol. I. 618.)

See Analyses of Common Felspar in p. 31.

* "The older strata of clay-slate alternate with the newer ones of mica-slate: when the mica-slate is awanting, it rests on gneiss, and alternates with it in the same manner as it does with mica-slate; when the gneiss is awanting, it rests on granite, and also alternates with it. These facts shew, that clay-slate is sometimes of cotemporaneous formation

therefore, a great coincidence in their analysis, we may infer that clay-slate is a felspar extremely comminuted, and little altered. The primary syenites and greenstones contain felspar and hornblende, which exist in granite. Limestone occurs in extensive beds intimately connected with gneiss, and it appears as a constituent in some granites*. In porphyry, the basis is various, but is generally a finely grained rock,

---

mation with mica-slate, sometimes with gneiss, and sometimes with granite." Jam. Mineralogy, I. 442. In p. 448. he notices that it probably passes into compact felspar.

[*] Chains of mountains in Canada are formed of a granite in which limestone is substituted for felspar. Kalm first mentioned them. Saussure has described a similar rock near Mount Cenis. Werner told Mr Pinkerton, that he regarded it as a truly primitive limestone.—In the Alps, this calcareous granite more frequently assumes the form of gneiss.—Pinkerton, I. 209.

Primitive limestone often alternates with granite, and has been often found to assume granitic forms.—Ib. 214.

It may therefore be inferred, that mountains of granitic limestone had existed, and from their nature had been more rapidly disintegrated than other rocks.

rock, often similar to clay-slate, and inclosing crystals of felspar. The minerals of the secondary strata may, in like manner, be traced to the materials of granite, sandstones to quartz, clay-slates to felspar, traps to felspar and hornblende, &c.

May we not then infer, that all the primary stratified rocks have been formed from unstratified and more primary granite? Quartz, felspar, mica, hornblende, occur in them all. Felspar, like quartz, is found in all the strata *; and is a substance easily altered, and very liable to decomposition, while quartz is unalterable. And clay-slate, which comes so near to felspar in nature and position, presents its constituent parts with those alterations to which its decomposition gives rise.

8. This

---

* See Jameson's Mineralogy, vol. 1. p. 375. for a view of the extensive distribution of this important mineral.—Beds of compact felspar, in a pure state, occur in gneiss, and other primitive rocks.—Ib. p. 381.

It should be remembered, that felspar forms from 70 to 80 *per cent.* of the mass of most granites.

3. This relation between the materials of granite, and those of the stratified rocks above it, is the closer, the nearer the stratified rock is to the granite, in order of position.

This is evident, from considering that gneiss contains the quartz, felspar, and mica of granite; that mica-slate contains only its mica and quartz; and quartz rock its quartz; that in these rocks the instances of alteration gradually increase from granite, and are more perceptible in clay-slates, sandstones, porphyries, &c. which are farther removed in position from the central granite *.

4. A mechanical structure of all the stratified primary rocks will alone explain the uniform

---

* The constant passages of all these rocks into each other, in a regular order, from clay-slate, mica-slate, quartz rock, and gneiss, to granite, will be remembered here. We have to account for this constant transition, and also for the difference between unstratified and stratified rocks.

form order which they observe in their position above granite.

This will arise from the following considerations.

A regular stratification implies the idea of a mechanical deposit from water; and that this is indeed the true explanation of a regular series of beds, strata, or layers, is generally admitted.

If it be admitted as to the secondary rocks, why should it not be admitted as to the primary ones, since, as far as stratification is connected, no difference appears between these two classes of stratified rocks, which graduate into each other?

Marks of mechanical structure appear in all the primary stratified rocks. In gneiss, the particles which constitute the mass of the stone, are irregularly disseminated through it in numerous cases, and pieces of rounded quartz often appear in it. I am aware that there are marks which distinguish some of these from rolled pieces in more secondary strata, and that they are commonly denominated cotemporaneous.

ous. I shall therefore at present only infer, that a mechanical action appears from the fragmented crystals of which gneiss consists, being very unequally distributed in the rock, and from masses of quartz and felspar constantly appearing in it*.

In mica-slate the mechanical appearances increase, and the inclosures of quartz bear two marks of mechanical action; they may be withdrawn from the rock with surfaces presenting marks of wearing; and they often exhibit

---

* Werner had in his possession a nodule of gneiss, inclosed in granite.—(Jam. Min. of Scottish Isles, I. 41.) Saussure observed a mass of granite, which contained an oval piece of gneiss. It is probable that these granites were parts of stratified granite: for Dr Grierson (Wern. Trans. II. 384.) gives a minute description of fragments of compact gneiss occurring in the stratified granite of Galloway, and mentions particularly the distinctness of juncture, and the "granite and gneiss alternating a vast number of times;" whence I regard the whole as gneiss. Saussure, § 661. gives accounts of granite imbedded in mica-slate and gneiss.

very flat masses, lying always in the direction of the strata, and presenting examples of a compressing force having acted upon them when in a softened state *.

The mechanical nature of Quartz rock, and its being in many cases only an aggregate of fragments of quartz of all sizes, has been already stated, when giving an account of its position. It is in fact, from all the appearances, a highly indurated sandstone †.

Clay-slate

---

* Saussure, § 1366. describes a mica-slate inclosing quartz in the form of lentiles, of some inches in length, and one or two in thickness. In Dr Macknight's description of the mica-slate of BenLedi, " the masses of quartz often appear as if closely wrapped round by the substance of the slate, like what might have taken place had the slaty matter formed around them as a sort of nuclei by the accretion of successive layers."—Wern. Trans. I. 291. He calls them cotemporaneous.

† Saussure, in § 763. mentions a sandstone graduating into gneiss. Kirwan mentions a sandstone near Prague, graduating into hornstone and granite, (Geol. Essays, 209.) Dr MacCulloch, in his description of the gneiss rocks in Guernsey, (Geol. Trans. I. 9.) mentions, that they have every variety of constitution, from a true granite to gneiss, mica-slate, felspar only, and quartz only.

Clay-slate is closely associated with and passes into mica-slate; when purest, it has all the characters of a deposit of finely divided particles of matter, and when Mica is entangled in its substance, the plates of mica, as in gneiss and mica-slate, are laid parallel to the direction of the strata.

The constant *passages or trasitions* which gneiss, mica-slate, and clay-slate present, is another proof of mechanical structure. Gneiss and stratified granite form in many situations but one rock. Gneiss and mica-slate pass into each other by the most insensible gradations. Quartz rock often contains mica. Mica-slate and clay-slate are allied in the clost manner *.

---

* See, as above, Jameson's Geognosy.—The appearance of gneiss, &c. is ever varying. Granite, in mountains composed of it, is the only primary rock in which I have observed any approach to a regularity of grain and structure, on the large scale. On Lochnagar mountain, I could perceive no difference in the appearance of the rock in a ravine] 1200 feet high: gneiss is very different.—Mr Horner (Geol. Trans. I. 185.) observes, that in the Malvern Hills, very few rocks

The remarkable fact, that the largest-grained gneiss is the oldest, or next to the granite, and that the grains decrease in size as the rock is newer, is another proof of mechanical deposit. For this appearance, and that of the transitions, can be only explained on the supposition, that the fragments of crystals which constitute these rocks, were let fall from a liquid in which they were suspended, and that the larger fragments, being from their mass less resisted in their descent than the smaller ones, fell first, with least mica; that the felspar grains fell more slowly as they became smaller; and that the mica increased in quantity, from the resistance which the shape of its plates opposed to its descent through the liquid.

In the facts observed by WERNER with regard to mica-slate and clay-slate, the above inference meets with new proofs. In mica-slate, as in gneiss, the largest grained is always the oldest, the fine slaty the newest. And mica, from

---

rocks of a homogeneous structure appear: they are unstratified syenitic rocks.

from the form of its small plates of crystal, is of all the simple minerals that one which would remain longest in suspension in water, excepting finely divided particles of felspar and clay*. If we allow this simple explanation, we shall be furnished at once with the cause why mica gradually increases from the oldest gneiss to the newest mica-slate, and as gradually diminishes from the oldest clay-slate strata, to the newest, which contain none of it†. We also see the reason why the order of the rocks is, Gneiss, Quartz rock, Mica-slate, and Clay-slate.

---

* Mica descends even to various alluvial deposits; and to sandstone, wacke, amygdaloid, basalt, &c. Jameson's Mineralogy, I. 454. Can any difference be shewn between the scales of mica in these and in the more primary strata? "It sometimes forms short beds in granite and other primitive rocks; or it appears in globular, oval, tuberose, or irregular-shaped cotemporaneous masses in granite or gneiss."—Ib. 454. Is not this a description of appearances different from those of a chemical precipitation?

† Dr Macknight describes isolated masses of quartz, with the layers of clay-slate lapped around them, and obeying exactly the irregularities of their various shapes, (Wern. Trans. vol. II. 400.)...He infers, from the aspect of the mica-slate

Thus a cause connected with their mechanical structure explains their order of position around the globe. But, as this subject is capable of direct proof from experiment, I have endeavoured to strengthen the above conclusions by an appeal to that test. Experiments with a view to the illustration of Geological facts have certainly been made too sparingly. How much is it to be wished, that a well-furnished laboratory were set apart for this purpose alone.

A wooden box was constructed, six inches square and nine feet in height, provided with a moveable bottom, by which a square tray about six inches deep, could be introduced. Two sides of this tray were formed of glass, to allow an undisturbed inspection of its contents. When the

---

slate strata near Loch Lomond, that the undulations were produced by deposition from a fluid affected by currents. This is certainly calling in a mechanical cause to act; and from inspection of much mica-slate in the same country in 1811, I drew the same inference.

the box was filled with water, the tray being previously inserted above its bottom, various substances previously arranged were let fall through the liquid, so as to imitate, as nearly as possible, the mechanical suspension and deposition of the stratified rocks. As the separation of the constituent parts of granite by pounding is difficult, granitic sand unconsolidated, and presenting the proper proportions of quartz, mica, and felspar, was selected from a quarry. The first attempts were not productive of good results, from the rapidity with which the fragments fell down: this was prevented by introducing into the box an endless coil of hair, resembling the rope-engine of Vera, and turned slowly by the usual means. The gentle agitation thus communicated to the water, retarded the deposition; and when the materials of small-grained granites were let fall, granitic sand was never reproduced, but a gneiss graduating into mica-slate, most mica being uppermost. With mica-slate in powder were mixed various portions of blue clays, reduced to a fine division by burning; and such results as had been anticipated, appeared. Felspar is a heavier substance than quartz, and in grains of equal dimensions, falls quicker; but in gneiss the grains of felspar are in most cases larger than those of quartz. It will be easily seen, from these trials, that in substances descending through water, the resistance arises from the specific gravity and the size and form united.—With water saturated with salt, the results were still more distinct.—These simple experiments may be easily repeated; and perhaps they afford one of the best modes of studying the nature of the stratified rocks.

I shall proceed to another proof of mechanical formation, derived from the *outgoings* of the strata of the primary stratified rocks. The outgoings of gneiss strata are always lower than those of the granite on which they repose; and higher than those of the mica-slate, which commonly covers them. And the outgoings of mica-slate strata, are lower than those of the gneiss on which they rest, and higher than those of the clay-slate which usually covers them.

Upon the theory of an origin from Granite, and of a mechanical deposit from a liquid, this is exactly what should appear in these strata. For the materials of gneiss, mica-slate, and clay-slate, falling down above a central unconformable nucleus of granite, the finest particles would be dispersed to the greatest distance, and would cover the outgoings of the rest. The mica-slate would go beyond the gneiss, and the finer particles of the clay-slate would in their turn cover the mica-slate. So that the outgoings of the strata would be the same with what we observe.

The mantle-shape of the strata of gneiss, mica-slate, and clay-slate affords another proof of mechanical deposit around a nucleus. This is observed in the most primary mountains only, as in those of the Hartz, Saxony, the central groupe of Scotland, &c. The Wernerian descriptions here are precise and accurate; they alone exhibit the appearances of nature; just as Werner has given one of the best descriptions of unstratified Granite. Thus, in the Hartz mountains of Germany, the granite of the *Brocken* rises up through all the strata. The strata clay-slate are wrapped around it, gneiss and mica-slate being wanting. The other strata succeed, each with lower and lower outgoings, in the surrounding hills; each stratum reaching a lower level the farther it proceeds from the central mountain *. All this is evident, if a mechanical deposition be supposed.

The constant alternation of beds of gneiss with those of limestone, mica-slate, and primary trap, &c. shew, that on the supposition of a chemical deposit from a liquid, the causes necessary to explain the phænomena must be extremely complicated, and at present entirely beyond

---

* Jameson's Geognosy, p. 71.

With regard to the formation of strata on planes of great elevation, some facts are ascertained. The debris on Salisbury Crags lie on the hill at an angle of 50° nearly. Some parts of the debris on Ben Macdhui and Ben Nevis can scarcely be estimated at less than 55°. On Carntoul, some of the debris above the Blue Lake averages 60°. Humboldt has remarked on the deception which arises in estimating the angle at which a mountain rises, and has described a contrivance for measuring accurately.—See also Dr Macknight's observations in Wern. Tr. vol. II. p. 402.

yond the range of our knowledge either of chemical solution or precipitation. Here no explanation has been supplied, nor any of that idea of gradual passage from perfect chemical to perfect mechanical deposits, upon which the Geognosy of Werner is founded, and of which Nature offers to us no trace [*]. On the theory of a degradation from large granitic masses, the presence of alternating strata confirms their mechanical nature. For the disintegrating causes which act on the granite must, from their nature, act unequally, and alternating strata of the same rocks be in many cases produced on the same spots. The action of rapid currents will alone tend to produce them [†].

---

[*] "The primitive parts of the crust of the earth are *entirely chemical productions;* whereas in the newer and newer, we find a beginning and increasing quantity of mechanical depositions."—WERNER's second inference in Jameson's Geognosy, 69. This implies a constant mixture of chemical and mechanical deposits in many rocks.

[†] This action of currents has been adduced by Mr Fleming to explain some appearances in Papa Stour in Shetland. (Wern. Trans. I. 173.)

The appearance of thin alternating with thick strata, is another proof of mechanical deposit. This takes place in our experimental imitations, and may be referred to the same cause which produces alternating strata.

It still remains to apply these principles to that regularity which is observed in the direction of the greater part of the strata. Few facts have been more hostile to the Huttonian hypothesis than this. To suppose the action of heat from below upon strata of gneiss, slate, &c, *previously* consolidated, is to introduce a power of irregular and violent action, displacing the strata in every direction, and to a great extent. Against an explosive agent, regular bearings of strata to a great extent are entirely opposed. From all my observations, I have been led, with many others, to the idea, that the great masses of the strata have been formed in the spots where we now see them. But no inconsistency will arise in supposing that they were deposited *above* those nuclei whence they derived their materials. These materials did not come originally from above, but arose from the disintegration of the masses on the surface.

From all observations it does not appear, that there exists one general direction or dip of strata, which is the same in primary, transition, and secondary rocks. The mantle-shaped strata which invest granite mountains, the great regularity of their outgoings in primary tracts, the higher inclination of their strata from their resting on granite, and their direction and dip being conformable to those of the sides of the fundamental rock, all give rise to a great difference in the appearance of these strata from that of those of lower situations. It is chiefly in the latter, and at some distance from the mountains of granite, that a general direction is visible. In extended tracts of mica-slate and clay-slate, it always appears, as in Scotland, where I have traced it from the extremity of the valleys in the mountains of Mar, to the shores of Argyleshire at Oban. Throughout the whole line of the Grampian chain, the strata run from N. E. to S. W., and this general direction is the same with that of the range of these mountains. In the numerous narrow glens of Mar and the forest of Avon, this appearance ceases, and the mantle-shaped strata of Werner come into view. HUMBOLDT, from his observations in Germany, Switzerland, Italy, Galicia, and South America, has inferred a general direction of the strata in all these countries, from N. E. to S. W. at an angle of 50° with the meridian, and a dip under an angle of from 60° to 80° to the N. W.

No fact in Geology can be more interesting than this; and, if connected with other appearances, it leads to conclusions of the most useful kind. HUMBOLDT himself draws from it that inference to which all the principles above developed tend, That the direction and the acclivity of mountains and mountain ranges, are phænomena *subsequent* to the formation of the original mountains themselves. I confess that it was this confirmation of my ideas by a traveller so illustrious, that has led me to state them so generally.—" The strata of the origi-
" nal mountains appear, amidst all the angles
" of direction and dip at present observable,
" to have existed before these changes of the
" surface

" surface of the earth. They are the same at
" the summit of the Alps, and at the bottom
" of the deepest mines. When we travel for
" fifteen leagues over strata of clay-slate, which
" are parallel to one another, and dip at an
" angle of 70° to the N.W., we can no longer
" believe that they were deranged strata, which
" were once horizontal [*]." Now, on the theory of a mechanical deposit from an extended mass of waters, this is exactly the appearance which we would expect to find in nature. A few mantle-shaped strata would be left around the central pyramids of granite; but the great deposits of rocks, both primary and secondary, would, from the transportation of their materials, take place rapidly and uniformly over extended tracts.

---

[*] See Von Buch's Description of Landeck, Appendix, p. 116.—120.

Humboldt hints at the cause of an appearance so general, and is of opinion that it can be founded only in the rotation of the Earth[*]. —In a spheroid covered with a liquid, through which mechanically diffused substances were falling, which is in motion on its axis from W. to E. and is not acted on by influences which produce vibratory tides, the suspended materials, from the combination of the rotatory motion with the diminishing velocity communicated to the waters from the equator to the pole, would assume in their deposit the diagonal lines from S.W. to N.E. [†]

Such would be the case in an uniform mass of waters. In a spheroid, on whose surface large masses of land were thrown up in clusters,

---

[*] Wern. Trans. vol. I. p. 107.

[†] It is remarkable, that in the Scottish mountains, the principal *choires*, or hollows, open to the N.E.

ters, discordances would arise, and the general result would not be always preserved. Enough of uniform direction of the strata would, however, remain to testify the regularity of the cause which had acted in their arrangement. And thus this explanation supplies us with another proof of a mechanical deposit of the materials of all the stratified rocks, if more proofs were wanted. The facts observed are inconsistent with the idea of a chemical precipitation. They form one of those links which connect intimately the science of Geology with the researches of Physical Astronomy, and exhibit new relations between the worlds which surround us, and our own globe.

These are the proofs which have appeared to me favourable to the mechanical origin of all the primary stratified rocks. They constitute a mass of evidence which explains far more of the appearances of nature than any other theory. I might here add to them, that proof which is derived from the fact, that no liquid solvent, but water, is attached to our planet, and that it could not be the liquid which dissolved all these rocks, because it is possessed of no such powers. Some geologists have indeed hinted at the probability of its solvent powers being brought into action by heating it to a temperature under 212°; but of this, also, the whole range of chemical science supplies us with no proof. It is not sufficient to prove that water can dissolve small quantities of silex or alumina, or larger quantities of those earths, if both be placed in it in a minute state of division*; water must have dissolved the whole masses of unstratified and stratified rocks, in order to accomplish the ends of the Wernerian Geognosy. It must, even in the metallic veins, have acted on all those metals, to which, at the present day, it possesses no relation of solution whatever †.—That the waters of the globe were present, at the formation of our unstratified and stratified rocks, is evident from the figure of the earth, the appearances of stratification, and the existence of water in them all. That it was present in the metallic veins, is evident from the water which they often inclose. The organic remains attest its existence when the secondary strata were deposited.—I am, however, unwilling to press this proof, for a reason already mentioned, that it is not from evidence of this kind that we are to attempt the interpretation of nature; but from the study of the rocks, and the simple minerals themselves. Without this one, all the other proofs of mechanical origin corroborate each other.

---

* Murray's Comparative View, p. 80.

† It is necessary to find precipitants, as well as to dissolve, and to have these acting and ceasing to act at various intervals.

---

intervals. The Wernerian principle is in fact bounded by the limited quantity of water belonging to our world. See Murray, ib. p. 87. for the best defence of the solvent powers of water. It is rather remarkable, that the progress of chemical science has added nothing to this principle of Werner, while many new facts have been observed respecting the action of heat.

It is now necessary to consider an objection to the whole of the above reasoning;—an objection to which I paid so much attention, that it alone constituted the chief reason why these proofs were not sooner placed in order; for it appeared for a long time to be insuperable. In a case of this kind, where the appearances of nature afford conclusions so simple and obvious to him who studies them, and yet where *one* fact cannot be explained consistently with our present knowledge of minerals, it is our duty to wait, and to examine. For it is certain, that one appearance not explained, and yet by its relations bearing on the explanation of many others, will overturn a theory completely.

It will, then, have already occurred to you, how, on the theory of a formation of all the stratified rocks by mechanical deposition solely, it is possible to account for the perfect appearances of crystallized minerals which we find inclosed in them all. Every observer is familiar with these appearances, which, with some propriety, are called cotemporaneous, because they are evidently of the same æra of formation with the rock itself, or nearly so. Thus gneiss, quartz rock, mica-slate, clay-slate, and all other rocks, from the oldest gneiss to the newest chalk, without one exception, enclose crystals of quartz, felspar, hornblende, garnet, actynolite, iron pyrites, topaz, and indeed all the minerals which are found in beds. These, too, often constitute a considerable part of the mass of the rock; as garnets in mica-slate. All are true crystallizations; and, with those larger and finer deposits found in veins, seem to have been formed by a process similar to that which we observe in our artificial solutions of salts. If heat was the agent, that heat which hardened, did not melt the strata, and therefore could not melt and crystallize the crystals which they involve, since they are as infusible as the strata themselves. If water was the agent, where was the space in which it could exert its energies, should we gratuitously bestow upon it the power of dissolving garnets or iron-pyrites? Let it be remembered, too, that every appearance indicates that these crystals were formed subsequently to the arrangement of the strata. They bear no marks of mechanical degradation; they have formed wherever they found room to shoot forth their crystals; and they are closely related to the space around them, from which they have never been removed since the date of their origin.

Upon the subject of the crystallization of minerals, few facts have yet been accumulated. Most theorists have felt the above objection; and finding it impossible to answer it, have passed it in silence. Some, like La Metherie, have supposed that felspar requires most water to crystallize, and must therefore be the oldest rock; but felspar occurs in every rock, from the oldest to the newest. Others have arranged hornblende, quartz, mica, magnesia, and the metals, in a regular order of relation to water, without one fact to support their ideas. The opinions of COUNT BOURNON *, and MR KIRWAN,

WAN,

---

* See Philos. Trans. 1804, p. 38.

WAN *, convey no satisfaction to the inquirer. They both suppose a complete solution in water, like WERNER, who explains the deposits of metallic veins by a succession of precipitates following each other, at times very distant, from the same solution †. At the present day, BERZELIUS has confessed his inability to explain the formation of a metallic sulphuret in a vein, excepting by the agency of the electrical fire ‡. Yet

---

* See his Mineralogy, vol. I. p. 22. (2d edition). Both speak of a precipitation of the molecules of quartz, carbonate of lime, &c.

"When a fluid holds in solution the integrant molecules of several different substances, the molecules of one substance pass between those of the others, and each obeying its own laws of attraction, crystallizes separately. There is not a metalliferous vein which does not contain examples of this," &c. Count de Bournon, in *Traité de Mineralogie*, tom. II. 192.

† Werner's New Theory of Veins, Dr Anderson's translation, p. 119.

‡ Berzelius' Attempt to establish a pure system of Mineralogy, &c. 1814, p. 19. *note*. The whole passage is a singular

Yet there are not wanting several facts, which, if extended, will afford us new views of that

---

gular example of assigning a cause, of the mode of whose action we have at present no means of judging.

"The opinion, that minerals have been produced by the fusing agency of a high temperature, and a consequent cooling, has not yet lost all its advocates, although a single decrepitating crystal, a single petrifaction, is an incontestible truth for all who can perceive what is proved by the agency of these. It is clear, on the other hand, that we often see crystals, which, according to what we have hitherto been taught by theory, never can, as such, have been dissolved in water; for example, sulphurets and arseniurets of metals. But here we must recollect, that in the solutions which are carried on beneath the surface of the earth, a power operates which we never can dispose of exactly in the same manner in our experiments, namely, electricity, and that which in our experiments is produced in the course of a day or two at most, may in the bowels of the earth require centuries for its developement. The blended masses of the globe, burst through and penetrated on all sides by intruding water, produce innumerable multitudes of electrical circuits, which cross one another in all possible directions, without impeding their separate operations, like the rays of the sun on the surface of the earth, and determine the that crystallizing proceſs which nature has employed, and still carries on. It is not, for instance, necessary to the formation of a crystal, that solution in any liquid should take place; nor has this process any relation to the air. For sulphur, corrosive sublimate, several metals, and other bodies, condense *in vacuo*, and the forming crystal must therefore arise from gradual deposits of matter in the state of gas. Silex has been sublimed in artificial fires, and is often formed in stalactitical appearances in the cavities of cooling lavas, of which the heat is well known not to be great.

Spallanzani found zeolites near the hot stoves of Lipari [*]. All the metals may be sublimed,

---

the eternal activity by which the masses of the interior of the earth slowly experience incessant changes, destruction, and new forms. Crystallizations, solutions, reductions, oxidations, take place here incessantly, under forms and proportions which art, unable to dispose of its efficient powers in the same manner, will never perhaps be capable of imitating."

[*] See his Travels in the Two Sicilies, vol. III. p. 58—69. Dr MacCulloch relates a sublimation of silex in his furnace.

(Geol.

blimed, and their gases condensed, in forms more or less crystalline*. It is not difficult to conceive of the formation of crystals from aërial substance; but it is not so easy to understand the progress of crystallization after a mass of matter has become to all appearance solid. This fact was first observed and reasoned upon, by Mr G. Watt †, in his experiments on the changes produced by slow cooling on a large mass of basalt. There the formation of a radiated structure, and spherical forms, continued

to

Geol. Trans. II. 275.) Breislac found siliceous stalactites on the walls of a house overwhelmed by the Vesuvian lava of 1794; and his experiments shew, that that lava, when flowing, could melt copper, but not silver.

Siliceous stalactites, like strung pearls, occur in Ischia, in the Solfatara, and in the Maremma of Tuscany, (Geol. Trans. II. 299.)

* The new blowpipes allow this to be done; but forty years since, Lavoisier gilt a plate of silver, by placing it above gold, in a furnace urged by oxygen gas. Arsenic, Tellurium, Zinc, &c. sublime at low heats.

† Philos. Trans. 1804, p. 290.

to go on after the mass had become solid, and for days, till at last small crystals began to appear in the stony substance. The change went on from glass to a rock inclosing crystals. The changes incident to glass, when it is exposed to heat for some time, without approaching fusion of its substance, in order to convert it into Reaumur's porcelain, must be ascribed to a similar arrangement*. When hot steel is plunged in water, in order to harden it, its particles take a crystalline arrangement, and occupy more room; for steel in the hardening process, decreases in density. These and other phænomena, shew us that motions and crystalline arrangements take place in solid matter. We infer these motions, with certainty, from the facts; but the subject of cohesion is too obscure to allow us at present to generalize them. They seem to be connected with an extensive range of phænomena, of which the malleable metals afford us one example. In hammering them, their density is increased, and heat is given out; but, in this operation, we can transfer a part of the substance of the metal, as lead, to a distance from its original place in the mass, and yet do this without overcoming the cohesive force which continues to act during the displacement of the particles.

---

* It has been well established, that Reaumur's porcelain is a species of crystallization; and of course, that glass crystallizes at two periods; in Prince Rupert's drops, when it is cooled rapidly, and in this porcelain where it is cooled very slowly.

It is obvious, that the admission of a principle of this kind may be applied to explain many appearances; and Mr Watt has referred to its action, with great probability, the change of lavas to that porphyritic structure, which is so common in them, the formation of leucites and augites in their substance, and the origin of all porphyries in general. Those limestones which pass slowly from a radiated concentric to a compact and crystalline arrangement, may have their change produced in the same manner *.

Let

---

* Philos. Trans. 1804, p. 297.

Let us next inquire if we have any analogous facts to guide us with respect to aqueous solution. Long crystalline ramifications of thin ice form every winter on our windows; and as the water which formed them could scarcely be in any case said to be a *continuous substance* over the surface of glass which it speedily runs down, it may be inferred that the size and symmetry of the arrangement which we see on the pane, does not arise from a crystallization of water over its whole surface at once, but follows from the gradual deposit of liquid from the rain or cooling air. Yet all the ice on the glass is connected in one form, which must have arisen gradually from successive deposits of water [*]. I have also frequently observed, that in saline solutions, such as nitre, if a quantity be allowed to evaporate very slowly at the ordinary temperature of our winter, we have not a mass of solid amorphous salt at the bottom, but very distinct and often large crystals, lying at pretty considerable distances from each other. Here the last portions of liquid must have deposited their salt, not in that level which we would expect, but around crystals to whose size and symmetry they contributed with the greatest regularity. The appearance is analogous to what we observe in every calcareous stalactite. There it is *one drop* charged with carbonate of lime, which hangs at the end of the pillar, and yet that pillar often exhibits large *folia* of calcareous spar, an inch in diameter *. These must have arisen from a gradual application of the successive particles of stone. When the same spar is formed in caves of basalt, at a distance from calcareous matter, the carbonate of lime of the basalt must have separated from the mass, and have produced the stalactite*. But the water necessary for each column is only a few drops, to percolate through the basalt, extract its lime, and arrange it slowly in a new form.

---

[*] It is not meant, that in no case as much water is on the glass at once, as there is of ice formed, but that the unity of the arrangement requires this explanation. What confirms it is, that on a close inspection, the ice will be found thicker on one part than another, and in several cases, parts of the glass will be altogether free from it. The whole of this very common appearance deserves minute investigation.

---

* Dr Clarke has described this fact, in the Grotto of Antiparos, (Travels, vol. III. 407.) It is seen in every stalactitical cave. Dr Clarke (412.) has drawn the inference of a continuous deposit, but not of a mechanical transit.

It is thus that for the most perfect and extended crystallizations, no large quantity of water is required. And, in many cases, the time necessary for them does not appear to be very great. M. METHUON appears to have been the first who examined accurately the formation of crystals in this mode. In a block of decomposing shistus, he watched the crystals of alum gradually enlarging; in other rocks, the progress of quartz, garnet, idocrase, and other minerals; and, after several years, he discovered the conditions requisite for their formation †.

---

* Dr Berger (Geol. Trans. III. 194.) mentions four caves in Rathlin, where this appearance is seen.

† See Journal of Science, No. 1. p. 128. M. Methuon has given a theory of these appearances, on which, in the present

In November 1816, I saw, in the botanic garden of Mr Templeton, at Malone, near Belfast, masses of amygdaloidal basalt, where deposits of mesotype had been formed in the cavities in the course of twelve months. He had first noticed their formation about two years previously; and having communicated it to some friends, the cavities in some masses were carefully scraped, so as to detach their zeolites, and the pieces being exposed in a moist situation, new formations of crystals ensued.

The inferences from all these facts become of great interest in our attempts to interpret the operations of nature in the formation of crystals. Yet these inferences might have been long drawn from the formation of an aluminous salt, which is constantly seen going on in alum-slate, and even in the specimens of that stone preserved in cabinets of minerals. The thick slaty masses

---

present state of our knowledge, it would be improper to remark. In the course of two years, by exposure of a mass of silico-calcareous earth in a moist situation, he formed crystals of quartz three quarters of an inch in length.

masses gradually, on weathering, separate and form into thin layers; between these, crops of fine silky crystals soon begin to appear, and, gradually increasing, push the layers to a greater distance as they expand in size. This appearance is seen on the large scale, and in great perfection, at the Hurlet mine near Glasgow.—Should we not, then, be allowed, from all the appearances, to conclude, that crystallization may arise from the deposit of matter in the gaseous, the aqueous, or the solid state; that, if the expression may be allowed, a *dry* crystallization exists, or a formation of crystals, to which no more water is necessary than is requisite to convey to their point of union the particles of mineral substance, and which, in many cases, exposure in moist situations, or the water present in the atmosphere, is sufficient to supply *.

All

---

* Perhaps we here approach also to the explanation of one of the most anomalous facts in Physics,—the difference apparent in the action of Heat in large and in small masses. Lavas which will not melt silver, sublime silex; common

salt

All our late discoveries on this subject, tend to the idea that crystallization is a process entirely mechanical. The dissection of crystals, their modes of aggregation, their cleavages, and the strength of their structure, are evidences of the action of cohesive power. If in solid cooling matter, like glass or steel, the crystalline arrangement is produced; in other cases, the formation of regular forms may be assisted by such small quantities of water as can convey the molecules of solid matter to their destination, as part of an uniform crystal.

In mineral veins, and in substances which crystallize upon or within the substance of others, the difficulties of explanation have hitherto

---

salt is decomposed in kilns, and its soda sublimed to glaze the pottery; these, and other appearances, shew us an inequality in the action of this agent, which we would not expect to find.—The presence of watery vapour, which gives volatility to most substances, will not explain the phænomena well. May they be referred to that motion of substance above mentioned? Crystals may be formed more infusible than the rock in which they are imbedded, if a principle of this kind can be established from facts.

therto arisen from the employment of heat or water alone. In the example of the Portsoy or Hebrew granite *, which is from a vein, the explanation of Hutton was always untenable, because it supposed that the quartz, which is the most infusible constituent of the rock, continued fluid after the felspar, which is more fusible; and which, instead of impressing the quartz with its rhomboidal crystals, should have become solid after it †. So when crystals of hornblende, shorl, titanium, &c. shoot through rock-crystal; or when fluor-spar has given its cubic forms to pyramids of quartz which invest it, the most infusible mineral, the quartz, must have

---

* This granite is a compound of felspar and quartz, the quartz being compressed or modified in shape by the crystals of felspar. It is found in several spots, and is by no means so uncommon a mineral as was once supposed.

† The other explanation is equally unsatisfactory; for quartz, being not very soluble, should have crystallized before the felspar. This is Kirwan's supposition, from the small affinity of quartz to water.—On the *primæval* State of the Globe, Irish Trans. vi. 242.

have become solid after the others which traverse its substance, or give it an impression. In these numerous cases, no objection can arise to the existence of successive stages of crystallization from small quantities of water. The action of heat alone can never explain the appearances, nor is it necessary. Had it melted the materials of a vein completely, it must have presented a very different class of phænomena from what we observe. The regularity of deposits, and the penetration of matter, could never have been exhibited. Had it fused the nodules of quartz in mica-slate, it must have melted the adjoining rock at the same time. Had heat acted on the calcareous spar which often adheres to an oyster-shell, it must, to form complete crystals, have dissolved the organic remain, and rendered the whole rock around crystalline. Had water formed the same spar from a solution, that solution must have dissolved the shell. By admitting a formation of crystals by small quantities of moisture, the spar will be formed, the shell not acted upon, and the rock in which it is imbedded, not altered in its mechanical texture *. On the Wernerian ideas of solution in a liquid of the materials of a mineral vein, how could that vein contain, in its recesses, the necessary quantity of solvent? No appearance in the Derbyshire mines is more common than the following. A mass of quartz has been moulded on cubes of fluor-spar, and after these last have fallen off or been displaced by a shift, new crystals of fluor-spar and galena have succeeded to their scite. Here the action of a solvent, in situations where no room for it exists, is required by the Wernerian. On the principles above given, the difficulties disappear; water exists in sufficient quantities, in all rocks †, to continue the crystallizing process; the presence of a certain quantity of heat in more

---

* Dr Kidd (Mineralogy, I. 74.) mentions a shell lined with crystals of fluor-spar, in the mineralogical cabinet of Oxford.

† Of this there are many proofs.—Murray's Comparative View, p. 100.——When granite is bored through in sinking wells, the rock at some depth is found softer than at the surface.

more early stages may hasten, but would not impede the arrangement; and to its agency we may ascribe the fusion of the metallic parts, as when silver or gold penetrate quartz in minute ramifications *. All these ideas correspond to the

---

* Dr MacCulloch has described the confervas and other plants enclosed in chalcedonies, in Geol. Trans. III. 522. and has inferred, from the appearances, an aqueous and a sudden silicification. He observes, (vol. IV. 224.) that no action of heat or water alone, can explain the appearances of agates. Stalactitical forms, he thinks, can only arise from water; but the cavities could not be previously existing in a rock like trap, deposited from an aqueous solution.—In other places, he speaks of the *solution* of silex in water as a process still going on, (p. 266.), and describes the gradual filling up of fissures in the Glen Tilt limestone with calcareous spar, from an efflorescence to a solid carbonate, as also in action at present, from his finding in the cavities water charged with carbonate of lime, (p. 396.) He also mentions in several places a solution of the earths in water, as being unquestionably more perfect in Nature than in our laboratories.

Of this last remark, I can find no experimental proof in the whole range of Chemistry. Of what use are our interpretations the principles above given, and do not contradict any part of our chemical knowledge of the relations

---

pretations of Nature by experiment, if finding that water has no action in dissolving gold or silver, and but a minute one in acting on silex and clay, we admit, solely to explain appearances, that water dissolves these bodies in the large scale? In the Iceland Geyser, the water, which contains soda, and is hot, has dissolved a little silex, but lets part of it fall when it cools. It may also be noticed, that no one has yet shewn, from the *structure* of minerals, decisive criterions of the action of water or heat alone. Stalactitical, columnar, and radiated shapes, as far as our present knowledge extends, can be and are formed by the agency of both, and of course are peculiar to neither, as Werner has asserted they are to water, by an assertion which may be said to be almost anomalous in the history of philosophical induction.—(See Jameson's Geognosy, p. 38.)

On the principles given in the text, many difficulties, which have long embarrassed this subject, disappear. Is the solution of silex ascribed to its finer state of division in Nature? What proof of this can be brought, or what proof is necessary, since experiments shew us a divisibility finer than the senses can follow? By rejecting hypotheses of this kind, a true theory of Agates is perhaps approached.

relations of minerals to heat. They are confirmed, too, by two facts which all analysts mention;—that the most regular and clear crystal is never free from some foreign ingredient; and that a very large share of crystalline minerals contain matter mechanically blended through their sub-

stance

After repeatedly examining most of the agate cliffs in Scotland, from Stonehaven to Kinnoul, the inferences I have drawn are, (1.) That nothing in the *internal structure* of the agates bears marks of heat, colour excepted, from which the strongest conclusion of origin is afforded. (2.) That this fact can be associated with the nature of the trap rock which incloses them. (3.) That the impressions on the exterior surface, which is so universal a mark, added to the concentric zones being always impressed from without inwards, and never the contrary, attest that they had existed in a soft state *previously* to their being imbedded, and are decisive against the idea of infiltration, since the outer coats had first become solid.

I ought to add, that in several cases, in these rocks, I have found marks of the inclosures having been formed from the substance of the trap, as already described, and that in these, the surface of the nodule is different from that of the Agate-Ball.

stance to a considerable extent. How much assistance these ideas give to the explanation of petrified organic remains, is too obvious to be insisted on. The flint, chalcedony, or limestone, have filled the cavities of an echinus or a cardium; they have completely displaced the organic substance; and yet how delicately is every pore or line of the shell preserved! So much so, that no action of heat or solvent powers of water can be reconciled to one specimen. On a formation of earthy matter in the mode mentioned, the whole is well associated with all that we observe.

Thus the nature of crystallization, whether aqueous, igneous, or aëriform, seems to depend upon a principle of the same kind in all. The arrangement of molecules may go on either from matter condensing from the gaseous state, or from its being allowed sufficient motions by fusion, or from its slower transference by the action of water. We should not expect, on this explanation, to find any differences in the structure of crystals which could allow us to infer to which mode of formation they owed their origin; and accordingly none have been found *.

With regard to Granite, to which I now return, one proof of its origin from fusion, has been already given. We infer this from that separation of colours which constantly appears in it. Another proof, not so decisive, follows from its being unstratified, and of a peculiar structure, afterwards detailed under Basalt. The phænomena of granite veins afford a better evidence of the action of heat. These arise from its substance, and pierce the strata above them; while the latter never send down veins into the granite †. Every thing here is against the

---

* Does not the sandstone of Fontainebleau confirm the idea of a deposit from a small quantity of water? For there, the quartz, in grains, has displaced the limestone more or less perfectly, and assumed its form.

† See Mr Playfair's Illustrations, § 82. and § 271.—287. —Sir James Hall's description of the Veins in the valley of Palnure

the ideas of secretion or cotemporaneous formation. For the strata are disrupted, and displaced in many cases; pieces detached from their substance are frequently inclosed within the granite of the vein, as if floating *; in other cases marks of an indistinct blending of the granite and the stratified rock are observed †.

These

Palnure in Galloway, of which a model was presented by him to the Geological Society of London; (Edin. Trans. vii. 99.)—Jameson, in Min. Scottish Isles, ii. 173. describes the veins at Garvimore, on the Spey.—Lord Webb Seymour and Mr Playfair, on Glen Tilt, Edin. Trans. vii. 303, and Dr MacCulloch's recent examination of the same spot, Geol. Trans. iii.—Granite veins in Killas, at Table Mountain, Cape, are described by Captain Hall, in Edin. Trans. vii. 273.——Saussure seems to have been the first who examined granite veins in the Valoisine; Hutton the first who drew inferences. Dr Berger's Wernerian hypothesis is in Geol. Trans. i. 147. The number of these descriptions has much increased of late years.

* See the drawing of the veins at the Cape, Edin. Tr. vol. vii. *supra*.

† In Geol. Trans. iii. 349. Mr Horner has described a junction in Salop of granite and slate, where there is an indistinct

These are evidently effects of an injection of liquid substance from below. The only circumstance in the explanation of granite veins which has appeared to me defective in Mr Playfair's reasoning, is the assumption, that the rents have in all cases been produced by the liquid matter. For in several cases, like trap veins, they traverse the strata with but slight disturbances; and it may hence be inferred, that some of the fissures had been formed by another cause. On the theory of a wet paste of gneiss or mica-slate resting on a heated nucleus of granite, fissures would arise in the stratified mass, from its rapid contraction, and these rents would be widest below *. In other situations, the

---

distinct blending, and an appearance of the fragments of slate united by a granitic cement.

* At Coul in Ross-shire, the strata of gneiss contain many granite veins, " near which, at the outside curvatures of some of them, I perceived rents similar to what we might expect on bending a flattened mass of clay, nearly deprived of moisture."—Mr Allan, in Edin. Trans. VII. 129.

the appearances are certainly in favour of a formation of the veins by irruptive force. Let us add to these proofs that confirmation which arises from the close analogy between granite veins, whin dykes, and those dykes of lava which occur in the vicinity of several volcanoes.

The varying consolidation of the strata is another proof of the action of heat, for heat, acting on extended masses of stratified rocks, which it does not melt, must be a power of variable intensity *. Instances of variable consolidation occur in almost every rock.

The alternation of consolidated and unconsolidated strata still remains to be accounted for. In the explanation which I am about to offer, I only wish to be understood as stating a circumstance

---

* Here another difference arises between the Huttonian hypothesis and that here advanced. Their granite should melt much of the strata, because it acts when forming, on rocks deposited for ages above it: on the other principle, the rocks, as they form in strata, tend to cool the mass, and prevent their own fusion.

circumstance which will explain this appearance; but of which, though it is not contradictory to any known fact, we have at present no other proof but that if assumed it will afford a solution. The phænomena occur frequently: rocks of sandstone have layers of loose sand interposed; beds of soft clay appear under beds of limestone. Though these appearances are rarer in primary than in secondary country, yet they are sufficiently obvious in many places, to have been stated for a century as a remarkable circumstance in the constitution of the strata. When unconsolidated and unworn granitic sand, of sharp and angular fragments of felspar, quartz, and mica, is seen in a quarry of hard granite, the appearance cannot fail to call forth the most earnest inquiries *. The explanation which may be proposed is at least not inconsistent

---

* As at Carngall, six miles west from Peterhead, a vein of consolidated granite, bent nearly like an S, traverses a mass of unconsolidated materials of granite, of various consistency. The granite is white, and small grained.

ent with the nature of the agent which is supposed to have acted. If steam of great elasticity be supposed to be retained by compression within the substance of clay or sand, or fragments of rocks of any kind, that elasticity would be a sufficient cause for the prevention of the consolidation in those spots where it was present. For no agent can be assigned, which, when highly heated, could convey a greater repulsive power to the particles of rocks. Had circumstances allowed, I should have thought no subject more worthy of an extended series of experiments than this. Such trials, when made, will probably confirm the above suggestion.

The waving undulations and bendings of the strata form a frequent appearance in many rocks. Mantle-shaped strata must be waved, from their position; but a greater waving, often of the most gigantic, often of the most minute kind, is seen in gneiss, mica-slate, and clay-slate. These are interesting, from the mechanical forces of which they imply the action.

tion. The undulated structure of mica-slate is universal; it forms one of the characters of the rock. The flattening of its numerous inclosures of quartz, in directions parallel to its beds, affords a strong proof of the action of a compressing force. Rocks entirely crystalline, and deposited from solution, should, from the rapid nature of their crystallization, resist a compressing force, as they consolidate. But strata mechanically arranging, and at first in the state of a soft paste, must be subject to the compression produced by incumbent and lateral masses. That this may take place, the experiments of Sir James Hall * have shewn satisfactorily. No other

---

* On the Convolutions of Strata, Edin. Trans. VII. 79. A horizontal pressure, acting from above, produces a simple curvature; acting in conjunction with side pressure, or thrust, gives rise to convoluted folds. Sir James Hall used an instrument for illustrating these principles on beds of soft clay. A pressure acting from below, may also be called in.

Mr Playfair, § 204. has observed, that in the grey-wacke of the Berwickshire coast, the curvatures are simple, the bendings other cause can be found, which affords an explanation that agrees better with all the appearances in nature. It may be added, as an additional confirmation, that mica-slate and clay-slate, the rocks which, from their nature, are most susceptible of compression, are the most undulated among the primary strata. The structure of their layers renders it probable that a very slight pressure produced their waving aspect; or such a pressure as would arise from the deposit of successive layers of the rock itself.

The last proofs of the igneous origin of granite, arise from the density of the globe, and the chemical nature of its exterior strata.

We cannot penetrate far below the surface of our World; and the deepest mines and excavations

---

bendings being all in one direction, or round axes that seem to be horizontal and parallel to each other.

Dr Macknight (Wern. Trans. I. 291.) ascribes the waving of mica-slate to a cause acting at its formation.

vations are insignificant, when compared with a radius of nearly four thousand miles. The *Itum est in viscera terræ* of Ovid will probably long remain the dream of a poet. Even the highest mountains, as has been often noticed, bear only the same proportion to the Earth, as particles of dust do to an artificial globe. Nature has subjected to our view what is really useful, either to our comforts, or to the investigation of the truths which are derived from the study of her works. While we are deprived, therefore, here of actual observation, the specific gravity of the globe has been ascertained by means derived from astronomical science. This result, resting on the principle suggested by NEWTON, of the deflection of the plummet from the perpendicular, in consequence of the attraction of a mountain mass, has given to the earth a mean density of nearly twice that of the granitic and other rocks which compose its surface, or about five times the specific gravity of water *. Hence, allowing for the waters of the ocean, which cover three-fourths of its surface, and the lighter strata, which alone are subjected to our observation, it follows, that the parts of the earth beneath these, must be heavier, in order to compensate for the less dense materials above them. A structure to a great extent cavernous, is thus excluded. Respecting the interior, we may, however, infer something more than its density. Of all the rocks yet observed, granite, or unstratified rocks like it, occupy the lowest or innermost situation; but these compact rocks must encircle others far more dense than themselves. Yet, as we have no knowledge of non-metallic substances possessed of a specific gravity of more than four or five times that of water, it is a legitimate inference that denser matter, and of course the interior of the earth, is of a metallic

---

* See Dr Maskelyne, in Philos. Trans. vol. 65.; and Playfair on Shehallion, Ph. Tr. 1811, 347. The mean density

---

sity he infers from a survey of the rocks, is 4.7129......Dr Hutton of Woolwich gave 4.48 as the mean density. The Hon. Mr Cavendish, from experiments on a different method, gave 5.48....Dr Thomson, in his excellent History of the Royal Society, p.354. thinks it probable that it is about 5.

metallic nature. This inference is confirmed by the discovery of the metals of the alkalies and earths by SIR H. DAVY, and the extension thus given to the agencies of oxygen. The batteries of VOLTA, in 1808, and the operations on a Perthshire mountain, thirty-five years before, have united in forming this interesting result. No sooner were calcium and aluminum in the hands of their illustrious discoverer, than these ideas of the nature of the world arose. Wherever we look, we behold around us, in the great masses of the globe, compounds of oxygen, with metallic bases. These compounds must have originated by combustion; for the new metals inflame on admitting water to their substance. An explanation of Volcanoes was immediately inferred, from the admission of water to a part of the metallic interior. In their fires we may read much with regard to the origin and progress of the world.

How well these conclusions agree with those views of the nature of rocks, which have been given above, is sufficiently obvious. It would lead us, however, into an approach to the defective

fective reasoning already mentioned, did we attempt to explain how it has happened that so large a portion of the crystalline rocks should consist of three or four ingredients, quartz, felspar, mica, hornblende, aggregated in grains, and without any visible cement. It may be sufficient to state it as an ultimate fact; and to suppose, that as these minerals, than which we see none in higher or in lower situations around the globe, constitute a large share of its surface, they may also form a no less remarkable part of the internal mass which is next to them in position. That they have been originally formed by the combination of oxygen with metallic bases, is also a probable inference; and, when originating in this way, heat must have been evolved. Since most of the primary rocks, and granite itself, offer only fragments of crystals;—since there are examples of recomposed granite in every gneiss rock;—and since the occurrence of granites, having much of their mass perfectly crystallized, is not very common; it might not be improper also to infer, that even the materials of granite had existed in another state, before they received their present arrangement. The first state of its formation may not have been in fragments of crystals. This inference, however, it is not necessary to draw: it is sufficient to shew, that in its last or present arrangement, granite presents the effects of heat *.

We

---

* The subject of the Figure of the Earth, is becoming more and more connected with Geological Science. It is probable, that the varying density of the rocks, and the inequalities of the surface, from the presence of mountains, by producing irregularities in the direction of the plummet in particular spots, give rise to those differences of results which have been now observed in the mensuration of arches of the meridian, made with the most perfect instruments, and conducted with the greatest skill.

Mr Playfair (Nat. Philos. II. 305.) denies the fluidity of the Earth as a cause of its spheroidal form, from our having no evidence of the action of water, excepting in transporting and depositing the fragments and detritus of solid bodies; a partial and local action, and therefore insufficient to account for the spheroidal shape.

But may not that degree of fluidity which arises from the fusion of a large part of the superficial strata of a sphere, be

We have now arrived at the conclusion, that all the stratified rocks were not formed from

---

be a sufficient cause for the form of a spheroid of equilibrium, without resorting to the hypothesis which he has given?—This supposition is, that in a terraqueous body, of any shape, if the prominences be worn down, and the debris be carried to the lower parts occupied by water, where they acquire a horizontal stratification, and are afterwards consolidated into stone, such a body, in the course of ages, must acquire a surface every where at right angles to the direction of gravity, and consequently more or less approximating to a spheroid of equilibrium.

The whole subject deserves to be examined more accurately, with regard to the extent of depth and direction of strata. The observations which Mr Playfair has adduced, to shew that a large depth of the surface of the globe is in some spots exposed to our observation, are not sufficiently authenticated, and I have met with none others. Examples of very extended and continuous strata, of uniform dip, would assist much in the solution of this problem.

La Place, in a late memoir, has inferred, from the best experiments yet made on the length of the seconds' pendulum, in different latitudes, that the increase of gravitation from the waste of a former world like the present, but arose from rocks like our present unstratified granites. When formed by a rapid degradation, the heat remaining in the central mass would consolidate them, as they fell down in strata from a mechanical suspension in water. Water exists in all the strata; but it can neither dissolve nor consolidate them.—A great simplicity is thus introduced into our ideas of the structure of the world. Granite still remains the oldest rock which is exposed to our observation. No strata can be termed, with propriety, chemical, granite and unstratified rocks excepted, in which no mechanical vestiges are seen. As the primary strata all had their origin from granite, so the train of secondary

---

from the equator to the poles, follows the law which theory points out as the most simple; and hence he conceives, that the density of the layers of which the mass of the earth consists, must augment regularly from the surface to the centre. From this condition, he infers the original fluidity of the whole mass of the planet; a state which, according to him, nothing but heat could produce on it.

dary deposits would arise, in the same manner, either from a degradation of the granite carried to a greater extent, or from the disintegration of the primary strata, as they formed.—No Universal Formations, in the exact sense affixed to that term by Werner, would exist*; but as all the low land has arisen from the descent of materials from mountain chains of granite, this would supply such an uniformity of character as we find in the present strata, without presenting deposits perfectly uninterrupted. While the materials nearest to the granite formed mantle-shaped beds around it, the rest, farther removed, and falling more slowly, would exhibit a considerable regularity in their direction, in consequence of the arrangement impressed upon them by the rotation of the globe. This direction would become the more regular, the more secondary the deposit, till extended tracts of land gradually arose *. The action of the retiring

---

* Werner accounts, by extensive degradations, for the absence of many of the primary strata on particular spots.

In a country like Sweden, which, according to Dr Thomson, is composed chiefly of gneiss, occasionally containing beds of granite, (Travels in Sweden; 53.) the formation of such extensive strata of stratified granite and of gneiss, only differing from it in a slaty texture, may be supposed to have taken place by a rapid and extensive disintegration of granite mountains. Thick slaty beds, approaching granite, would indicate a more rapid deposit of their materials, than strata of gneiss, in which the same materials occur in the slaty form.

In Mount Rosa, granite and gneiss alternate, in beds nearly horizontal, (Saussure, § 2138.)

---

* It would be remarkable if traces of a theory so simple as here given, were not found in former geological writers. My reading has not, however, supplied me with many. Ferber and Pallas, observing appearances of granitic masses and shistus passing into each other in the Russian mountains, supposed that gneiss, mica-slate, and clay-slate, were formed from the detritus of granite, (Jameson, Min. of Scottish Isles, i. 156.) I am not acquainted with the nature of the proofs which they employed.—The next geologist who has made approaches to these ideas of the origin of the stratified rocks, is Dr MacCulloch, in the papers on quartz rock, &c. which he has given to the Geological Society. From his careful examination of it, (vol. ii. 464. ...and vol. iv. p. 266.) he has inferred its nature as being partly chemical, partly mechanical, and he has insisted that appearances

retiring waters would form the valleys, and model the whole of the surface; and large transportations

---

appearances indicate a consequent mechanical nature in mica-slate. It is to be lamented, that so able an observer as Dr MacCulloch, has not generalized more.—In Thomson's Annals, vol. VII. p. 387. Mr Weaver, M. R. I. A. is said to have read in March 1816 a paper to the Geological Society, in which, from the writings of Saussure and Von Buch, he infers unequivocal proofs of a mechanical structure in all the primary rocks, which he wishes to refer to the Transition class. He is also of opinion, that all the overlying formations of granite, porphyry, syenite, and trap, belong to the newest flœtz-trap of Werner. This paper I have not seen, nor any other account of but the above notice.

Perhaps I may be allowed to mention, that my own observations commenced in 1811, though three years before, when I had the first opportunity of seeing mica and clay slates on the large scale, at Ben Lomond and Luss, I had been much struck with their general aspect, so different from what the Wernerian Geognosy had taught me to expect in chemical deposits. Observations made in several tours through a great part of Scotland, led me, in 1813, to the formation of most of the views contained in these pages; and having never adopted the Huttonian or Wernerian theories, portations of materials, by the same cause, would give rise to appearances which are seen abundantly in all countries at the present day.

I

---

ries, I had always mentioned, in the annual courses of lectures which I have given on Mineralogy and Geology since 1811, marks of a mechanical structure in all the primary rocks.—More extended journeys were made annually till the end of 1816, when other avocations prevented, till lately, all attention to this subject. The reader, if he has carried his books to the mountains, and observed for himself, must have felt some diffidence in stating opinions opposed to those of names great and venerated. When I found that no theory could explain the nature of the relation which gneiss bears to granite, or the worn nodules in mica-slate, it was surely necessary to inquire and observe. I shall never despair of a true theory of the world; and I wish all that I have stated in this letter only to be considered as a contribution towards that end.

I now proceed to collect the proofs of origin afforded by the important series of rocks denominated, in general terms, BASALT and TRAP. In the system of WERNER, they receive the name of the *Newest Floetz-Trap Formation* *. The name of *trap* has been given to them from the appearance of steps observed in most countries where they occur; the word in Swedish signifying a stair. They have also received the name of *whin*;—a word peculiar to the south of Scotland, but now generally introduced into Mineralogy from the use made of it in the writings of Dr Hutton, and other authors.

To Werner, as usual, we owe the most accurate distinctions of the rocks of this class.

---

* Floetz-trapp Gebirge, Werner. See Jameson, Geognosy, 185.—206.

The chief of them are *Basalt*, properly so called; *Wacka*; *greenstone*, an aggregate of felspar and hornblende; *clinkstone*, and *trap-tufa* *: Pitchstone, amygdaloid, compact felspar, claystone, iron ochre, and other rocks accompanying these.

The passages of all these rocks into each other, have been well traced by many observers.

So important and numerous are the relations of granite and trap, that they alone, when well

---

[*] We ought to add to this list many portions of Syenite and Granite, which, from their positions, have been denominated *new*, and which are intimately associated with these traps. To do this, however, in the present stage of the inquiry, is not necessary, and might produce too great a complication.

Some difficulty also arises, from a complete want of terms to distinguish unstratified from stratified traps. In the primary rocks, a stratified granite is expressed by *gneiss*; but here nomenclature is silent. Excepting where it is otherwise mentioned, it will be understood, that, under the popular terms of Basalt and Trap, I express the whole series of unstratified rocks of this class.

well understood, will supply us with the true key of the formation of the world. Both constitute two great *formations*, and exhibit two different æras. Both are intimately related. In Great Britain and Ireland, we are supplied with the best opportunities of examining both; and the proofs which have been given of the origin of the one, will assist us in explaining that of the other. I shall state all that has occurred to me, either from the observations of others, or my own.

1. As far as *colour* is concerned, all the remarks and experiments formerly mentioned, will apply to basaltic rocks. Many greenstones, like that of Fairhead in Antrim, are on a larger scale of grain than many granites, and have often as well defined separation of colours in the crystalline fragments of which they are composed *.

2. In

---

* In some of these rocks, the colours of the felspar are not so well defined as in granite; and had my observations

been

2. In their *nature* of substance we find in the trap rocks the same general constituents as in the primary granite. Felspar is the predominating ingredient in them all, if we can depend upon the transitions which connect them so intimately. Greenstone, which is the principal trap, consists of fragments of felspar and hornblende, often as crystalline as in any granite. It connects, on the one hand, with syenites and syenitic greenstones, and granite; and, on the other, with the basalts of the finest and most impalpable grain*. These transitions are often

---

been more complete than they are, an obvious inference might have been drawn from this circumstance.

* "Certain varieties approach to wacke," Jameson, Geognosy, 194.

"Greystone passes into basalt," ib. 190.

"Clinkstone-porphyry passes, on the one hand, into compact felspar and claystone, and on the other into pitchstone and basalt," ib. 191.

"Clay passes into wacke; the wacke into basalt; the basalt often made with a rapidity which all who view a trap country have observed, and of which the primary strata afford few examples.

Should these transitions, which are so well marked in nature, and have been so well described by the Wernerian Geognosy, be denied, we find another proof in the nature of the chemical analysis of the trap rocks which are of uniform grain and aspect. One exception only appears. Wacke and basalt, on analysis, approach near to felspar and clay-slate, and contain all the ingredients of these rocks, with this difference, that the alkali in the traps is soda, while in the granite it is potash *.

In

---

basalt into greenstone; and this latter into greystone and porphyry-slate," ib. 197.

All authors allow an imperceptible passage from greenstone to basalt.

* Basalt of Staffa, Silex 48. Alumina 16. Lime 9. Iron 16. Soda 4. Water 5. *(Kennedy.)* with 1. Muriatic acid.

Basalt of Hassenberg, Silex 44.5, Alumina 16.75, Lime 9.5, Magnesia 2.25, Iron 20. Soda 2.6, Water 2. and a trace of Manganese, *(Klaproth.)*

Basalt Tufa of Calton Hill, Silex 50. Alumina 18.5 Lime 3. Iron

In this mode, when, from the fineness of grain and structure, the external characters of minerals cannot be employed, we approach to the nature of the rock by a knowledge of its chemical ingredients.

We may infer, therefore, from this relation, a common origin to all the unstratified rocks.

8. The resemblance between granitic and basaltic rocks has been remarked by many writers; and I shall mention, as briefly as possible, those

---

Iron 16.75, Soda 4. Muriatic acid 1. *(Kennedy)*.

Greenstone of Salisbury Crag, Silex 46. Alumina 19. Lime 8. Iron 17. Soda 3.5, Water 4. Muriatic acid 1. *(Kennedy)*.

Clinkstone of Donnersberg, Silex 57.25, Alumina 23.5, Lime 2.75, Iron 3.25, Soda 1.10, Water 3. Manganese .25, *(Klaproth)*.

Clinkstone of Auvergne, Silex 58. Alumina 24.5, Lime 3.5, Iron 4.5, Soda 6. Water 2. *(Bergman)*.

Allan's Tables.

The presence of soda connects these rocks with the ocean.

those circumstances in which they agree and in which they differ.

Felspar is the chief ingredient in both, when both are crystalline in structure.

Hornblende and iron increase in quantity in traps as the crystalline structure becomes smaller, and the rock approaches to a homogeneous mineral*.

The absence or small quantity of quartz is the chief distinction between granites and traps†.

The soda of the latter rocks is another difference between them and the former.

---

* It would be interesting to analyze the felspars of trap rocks, and discover if their alkali be the same with that of granites.

† The Crag of Ailsa has regular columns of a rock of much white felspar, quartz and hornblende, exactly between a true granite and a greenstone.—Dr MacCulloch, in Geol. Trans. II. 422.

A prismatic form appears in the granite of Arran, Devon, and Cornwall.

The inference which may be drawn as to origin, from the small quantity of quartz in traps, is obvious.

The structure of granite and basalt, as far as we can infer from the appearances on decomposition, is the same. Both occur, when unstratified, in distinct concretions. These always include a harder central mass, and the distintegration proceeds in regular layers which are concentric. The globular concretions of granite, and the decomposing spheres of basaltic rocks, exhibit a perfect similarity to each other*. Granite also sometimes presents columnar aspects.

The *general aspect* of these unstratified rocks is the same. Both form large mural precipices, often of great elevation †.

---

* Professor Jameson's description of globular distinct concretions of granite, applies perfectly to many basalts: "These concretions are composed of curved lamellar concretions, and always include a harder central mass. The spaces between these globular concretions are filled with granite possessing less solidity, and which decays readily, and thus leaves the harder central masses heaped on each other, or strewed about."—Geognosy, p. 105. He mentions globular and concentric lamellar as among the forms of Basalt, p. 187.—See Dr MacCulloch on the Granite Tors in Cornwall, in Geol. Trans. II. 67.

Both classes of rocks form dykes or veins in the strata above them. Those of granite penetrate the shistus and other rocks above it; those of basalt pierce through all the rocks above them, and through granite itself. From the last circumstance we may infer, that dykes of whin are of later origin than those of granite *.

---

† These precipices exhibit often a N.E. and Eastern aspect; as at the Cave Hill, near Belfast; Ben Nevis; and Glencoe. On Fairhead, the resemblance of the rock to that of a primary granite, in *general aspect*, is very considerable: the rents, wearing, &c. are so similar. The trap rock of the Cuchullin mountains in Sky, connects intimately with its syenitic rocks; and Dr MacCulloch thinks them parts of one irregular mass, (Geol. Trans. III. 54.) from the finest grained black basalt of Talisker, sometimes columnar, (57.) to the perfect form, structure, and aspect of granite, (63.) and a rock perfectly granitic, (73.) Mr Playfair has traced similar appearances.—In the county of Antrim, a pitchstone porphyry covers a considerable space in the midst of the trap country; and the observations of Mr Griffiths of Dublin tend to connect it with the iron-clay of the Causeway. Berger has described it minutely, Geol. Trans. III. 190.—Dr Murray mentions whin or trap as a rock into which granite insensibly graduates, (Comparative View of the Huttonian and

Pitchstone is a mineral intimately connected with basalt, which occurs in granite †.

Granite

---

and Neptunian Theories of the Earth, p. 248.) The remarks of Dr MacCulloch, in Geol. Trans. III. 52. are full of information on this subject.

Dr Beddoes, Ph. Tr. 1791. has a paper on the identity of granite and basalt; but the advance of science has rendered his observations of little value.

It is to be understood, that all the circumstances mentioned in the text, are not intended to prove the identity of granite and basalt, but their *relations* only. There are many differences between them.

* In Cruachan in Argyleshire, veins of porphyry traverse the granite and shistus of the mountain; and basaltic veins, passing into the same porphyry, accompany them.—(Dr MacCulloch, in Geol. Trans. IV. 121.)

† Pitchstone veins traverse granite in Arran, and basalt in Eigg. Dr MacCulloch found pitchstone in the granite on the summit of Carngorm....(Jam. Mineralogy, I. p. 279.)

There is a vein of pitchstone traversing a granite (syenite) at Newry in Ireland: it has been described by Dr Fitton, Geol. Tr. I. 278; it is about 2½ feet wide, and is seen for half a mile.

Granite sometimes affects the needle, as in the Hartz, on Goatfield in Arran, on Cruachan in Argyleshire, &c.* Dr MacCulloch found trap affecting the needle on the summit of Mount Glamich, in Sky†.

4. The connexion between basaltic rocks and lavas is not less obvious than with granite.

Analysis exhibits a great correspondence in nature; and both contain soda. A proof of this kind can only be, however, considered in relation to other proofs; for very few of the numerous varieties of basalts and lava have yet been analysed.

The fracture and aspect of many lavas is the same with that of many fine grained basalts.

---

* Dr MacCulloch, Geol. Trans. II. 430.

† This has been long noticed in various spots. See Geol. Trans. III. 95.

Trap rocks occur constantly in volcanic districts [*].

In the soils which both rocks afford by decomposition, a great resemblance has been traced [†].

Great cavities occur in lava, and in basaltic tracts [‡].

Most lavas are porphyritic or inclose other minerals; and many traps are so.

The minerals inclosed are nearly the same, in both classes of rocks [||].

Very

---

[*] So universally, that Werner founded his singular theory of Volcanoes upon their presence.—Jameson's Geognosy, p. 219. Porphyritic clinkstone, greenstone, &c. abound in Iceland.—Sir George Mackenzie's Travels, p. 371.

[†] The soil of a trap country has been well described by Dr MacCulloch, Geol. Trans. III. 10.

[‡] Van Troil mentions great cavities in Iceland, in lava.—Letters, p. 234. Caves are abundant in trap countries. Ferber, Letters from Italy, p. 132. gives a particular description of a cavity in the lava of Vesuvius of 1770.

[||] The Causeway basalt incloses quartz, calcareous-spar, arragonite, chalcedony, semi-opal, olivin, green earth, steatite, Very obvious marks of heat occur in lavas and in basalts, from changes of colour in the oxide

---

tite, analcime, chabasie, mesotype, and stillbite. The iron-clay of this coast contains the same minerals. Of these substances, quartz and calcareous-spar are common to all classes of rocks; but all the rest are volcanic. Chalcedony is peculiarly one; as in Teneriffe.—(See the Hon. Mr Bennet's description of that volcano, in Geol. Trans. II. 289.); and so in Iceland.

Zeolite occurs in lava in Teneriffe.

The promontory of Fairhead is a greenstone containing *augite*, according to Dr Berger, Geol. Tr. III. 184. Specular or oligiste iron occurs in lavas, as in that of the last eruption of Vesuvius in December 1817, (Journal of R. I. N° 10. p. 201.); and I observed it lining the cavities of trap in Isle Muck, on the Antrim coast.—Olivin is a very constant product of lavas. The appearance of Chalcedony is sometimes exactly like that of small spheres in a lava, as in specimens from Faroe and Iceland, (see Mr Allan's details in Edin. Trans. VII. 257.) Minerals incapable of solution in our liquids are found connected with trap rocks; as threads of native copper crystallised in mesotype, some of the sprays of metal forming the nuclei of the radii of mesotype in amygdaloid in Faroe.—(Allan, Edin. Tr. VII. 236.)

oxide of iron which they contain, to a bright brown or reddish hue*.

Vitreous coatings occur in the sides of whin dykes in Faroe, Iceland, &c.†

The glassy felspar of porphyritic lavas is often changed to a substance like enamel, the same which is formed by the fusion of the spar. In pitchstone a similar change has been described ‡.

Lavas

---

[*] The effect of heat and air in altering the iron oxide in rocks which contain it in abundance, is well known, and arises from an evident change of the quantity of oxygen combined with the metal. I have traced much of this appearance in basaltic country: thus, at Portrush, the whole of the upper layer of trap, for three inches of thickness, in a quarry adjoining the celebrated shell rock, is of a brown tinge. In other situations, I have compared specimens of the same rock altered by artificial heat, with those changed by natural processes and by weathering, and have no doubt of the action of heat and air in many cases of this kind.

[†] Sir G. Mackenzie observed a vitreous coating on the sides of whin-dykes in Faroe and Iceland.—Edin. Trans. VII. 224.

[‡] By Dr MacCulloch, in Geol. Trans. III. 94. In Sky, the small grains in the pitchstone contain a whitish enamel;

and

Lavas often exhibit distinct columnar appearances, like basalts; and this adds an important link to the evidence, because the same trap rocks occur in their own and in volcanic districts in both columnar and other forms*.

Lavas frequently form dykes possessed of a very great resemblance to whin dykes†, and thus are connected with granite.

Pitchstone

---

and the layer grains in larger cavities of the same rock, have this enamel only at the surface, while the glassy felspar is perfect in the centre.

* Dolomieu, (Etna, p. 456.) enumerates many examples of basaltic columns in the Lipari Islands, and in Sicily. Daubuisson acknowledged the igneous origin of the Basalts of Auvergne, after visiting them. Mr Bennet found ranges of columnar lava in Madeira, (Geol. Trans. I. 395.) and columns of lava in a dyke, at right angles to the strata.

In the eruption of Vesuvius in December 1817, "the recent lava assumed the aspect of basaltic columns."—Signor Monticelli's report, in Journ. of Science, N° 10. p. 201.

† A dyke in lava, is drawn in one of Sir W. Hamilton's plates, in the *Campi Phlegræi.* Mr Graydon has described the

Pitchstone is a mineral common to countries of both rocks [*].

Lavas sometimes present an uneven surface of a crimpled aspect, from their motion as viscid fluids; and beds of amygdaloid have been found offering the same aspect [†].

Sir James Hall's experiments shewed, that the stony character of basalt was no objection to its having been formed by heat; since though traps melt easily into glasses, yet by slow cooling a stony aspect appears always in the mass, and the glassy character entirely disappears [‡].

These

---

the dykes of Somma, near Vesuvius, in Geol. Tr. III. 233.—They are evidently fissures, or cracks of the hill from top to bottom, into which a different kind of lava has flowed, homogeneous, compact, and often presenting columnar appearances.—Hardened jaspers, and other clays, occur in volcanic and trap countries, near the dykes.

[*] See *above*.

[†] Sir G. Mackenzie noticed this singular fact in the amygdaloid beds of Faroe.—Edin. Trans. VII. 221.——See also his remarks on lava and trap, *Travels in Iceland*, p. 360.

[‡] Edin. Trans. vol. v. p. 44.

Mr Watt melted seven hundred weight of basalt, and has

These are the principal marks of resemblance between these two important classes of rocks.

5. Basaltic rocks are seldom stratified, when observed on the largest scale. The same remarks which apply to the stratification of granite, have a close relation to them. Their most common character is a disposition in distinct concretions, columnar, tabular, globular, and concentric lamellar *. This connects them with granite.

6. Since all these unstratified rocks possess so many relations in common, I shall next inquire

---

has accounted well why *all* the characters of the original rock do not appear after fusion.—Phil. Trans. 1804, p. 296.

† Jameson's Geognosy, p. 187.

quire into what is known with regard to the structure of their substance.

The globular form is evident from the decomposition of many basaltic masses in concentric lamellæ, like granite, but more distinctly marked.

The columnar structure varies considerably in distinctness and size. Basaltic columns are of all sizes, from a quarter of an inch to twelve and fifteen feet in diameter; and from an inch to upwards of two hundred feet in height. The largest columns, in general, have fewest joints. A gradation of grain appears to accompany their structure, the largest columns, like those of Fairhead, possessing the largest and most crystalline grain; the smaller, like those of the Giant's Causeway, having the most compact and uniform texture *. The absence of

---

* Berger has noticed this of dykes, Geol. Trans. III. 228.

The most compact, hard, and sonorous trap, is that of the pillars of the Causeway itself, and those of a small colonnade of inclosed minerals, and the consequent homogeneity of texture, render the basalt more apt to assume the columnar aspect, and give a greater precision to the joints into which the columns divide *.

That these columns are not true crystals, has been long known; and that they are not, indeed, crystals at all, may be inferred from their irregularity of form, and from their not being divisible in the method of HAÜY.—The best views of the Causeway have long exhibited the principal appearances connected with the joints. They represent, too, the convex and

---

lonnade at Craighulliar, about two miles from it. There, too, the joints are of the greatest regularity yet known. No inclosures appear, excepting a few traces of steatite.

* "Basalt passes into greenstone, in the most imperceptible manner: in the first stage, the felspar exists under the form of short, scaly parts, either white or greenish; the texture becomes more finely granular and crystalline; the fracture in the great is not into flat conchoidal pieces, but more usually into irregular and blunted fragments."—Dr Berger, Geol. Tr. III. 184.

and concave surfaces which each joint possesses, and their great equality in thickness*. The number of convex and concave surfaces visible to the eye, in twenty thousand columns, which constitute the mole or pier, appears to be as nearly equal as that organ can estimate. No column is without joints. All exhibit some marks of shrinking. I observed one column of nine, several of four sides, and the pretty exact pentagonal one. Six-sided columns are the most common; but the general or first impression is, that of a far greater regularity than an accurate inspection afterwards justifies.

On the eastern side of the mole, the columns become a little larger; in the middle, and on the western side, they are most uniform. On the whole, the eastern side has less uniformity, and the joints are more frequently and irregularly

---

* The two prints, by Vivares, 1744, from drawings, by Mrs Drury, still exhibit the most accurate views of the Causeway itself. The copies which I have seen, are published by Boydell, 1777.

regularly cracked *.—A few joints have both surfaces convex or concave.—It does not appear that any thing as to their formation can be inferred from their dividing with either surface uppermost, or from their position; since columns appear in all positions from horizontal to vertical in many countries, without exhibiting marks of shifting †.

We

---

* All these remarks refer to the Mole of the Causeway itself, or rather, to the three divisions into which the pier is separated.—From numerous observations, it appeared to me that the basalt on the west side was of the finest grain.

† I have not seen columns dividing *below* into smaller ones of the same formation, though their division into such *above*, is one of the most common appearances in basaltic colonnades; as in Port Noffer; above the entrance of the Cave of Fingal, and in many other places. This circumstance deserves attention.—I join Dr MacCulloch in remarking, that Staffa has been much exaggerated in height; and I have seen no engraving of it which makes any approach to mineralogical, and scarcely to general accuracy.—The Causeway has been drawn with great truth and precision by Mrs Drury, by Mr Hamilton, by the artist employed

We are therefore left to examine the joints themselves; and here any observer cannot fail to notice, that his hammer detaches in the direction of the sides of the column, large splinters, in which portions of spherical forms are discernible.

On examining farther, a radiation from a centre is seen in each joint, proceeding towards the sides and angles; and this is most perceptible, when weathering or incipient decomposition begins to display the structure of the stone. This radiation may be distinctly traced in all the columns of the coast; and is more evident in the joints at Bengore than in the smaller and more perfect joints of the Causeway.

On carrying the dissection farther, the triangular projections, or *spurs*, as they have been called, separate by slight blows from the joints; for they are only attached by a slight connection; and a perfect contact of rock is made only

---

ployed by the late Bishop of Derry; and more lately, the admirable drawings of the last person have been corrected and extended by Mr Griffiths of Dublin.

ly on one small point, while a smooth, and often shining surface, of a rounded form, is presented over the rest of the contact.

On carrying the hammer round the sides of each joint, and impressing blows where the radiated structure of the inclosed spheroid appears to terminate, other angular pieces may be detached, and a spherical surface remain around the whole of the joint. This is accomplished more easily, and in greater perfection, on the concave surfaces; but it can also be done on the convex ones.

It may thus be seen, that each joint consists of a spheroidal nucleus, occupying a greater part of its mass, and of matter more loosely attached, constituting the prismatic form; and that compression arising from the mass, would account for the appearance of a columnar structure originating from an assemblage of spheroids *.

The

---

* Dr Richardson, in Irish Trans. vol. x. 1806, gives pretty good views of the joints, though the appearance of their

spurs

The basalt of the joints is thus intimately connected with that of a coarser grain, which decomposes, like granite, in concentric layers. The whole series is thus related in a structure, of which, however, we shall find other proofs.

It has been long observed, that where the basaltic rock presents numerous inclosures of other minerals, or becomes amygdaloidal in structure, the prismatic forms disappear *. The nature of the rock always changes with the perfect

---

spurs is exaggerated: he gives weathered and fresh aspects of the columns, but never hints at a structure *within* the joint. On the other hand, p. 104. he carefully distinguishes the onion or concentric basalt from that of the columns. " I have not been able to discover subordinate forms, or an *internal construction*, in any of these basalts,"—(columnar, irregular prismatic, or tabular), p. 103.—In Mrs Drury's prints, (published 1777 by Boydell), the spheroids inclosed in the joints are distinctly delineated and described.

* Raspe makes this remark in 1777, *On German Volcanoes*, p. 75.—So in Staffa, Dr MacCulloch, Geol. Trans. II. 504. where, like him, I found no zeolites in the most perfect and dense columns.

perfect or imperfect state of columnar structure. This fact connects the *nature* of the rock with the appearances of its *structure*; and it may be inferred that the two are closely united. The perfection of structure at the Causeway and Craghulliar [*] must thus be connected with the homogeneous nature of the stone of these columns. Now, glass, which is an uniform substance, presents columnar appearances, if it be cooled rapidly; it has only a vitreous texture when cooled slowly in the annealing process. The texture of the drops known by the name of Prince Rupert, was first imperfectly traced by Hooke in his Micrographia [†]. The late researches of Dr Brewster on light [‡], which have given rise to an entirely new branch of science, shew us that these drops have the same powers with other crystalline bodies in polarising light. When dissected, they present a structure entirely crystalline. Fibres, like those of actynolite, occupy the centre; around these, plates, also of fibres, and generally curved, are wrapped*.

---

[*] There is an imperfect drawing of this spot in Dubourdieu's Survey of the County of Antrim, vol. II.

[†] P. 33. He remarks, that "the larger fragments are prettily branched."

[‡] See Philos. Trans. 1814, p. 436. and 1815, p. 5. where a threefold cleavage of the drops is described. Slow cooling

This crystallised glass is formed by a sudden cooling of red hot substance in water. Our ignorance of the laws of crystallisation, prevents any attempt to account for this fact in a satisfactory manner†. But before applying it to the

---

ing destroys the crystalline texture which glass possesses when fused; rapid cooling fixes this texture, and renders it permanent.

[*] The easiest way of dissecting them, is to inclose three or four in a small box, just sufficient to hold them, with their tails projecting. Or they may be broken under the confinement of water. In these cases, parcels of fibres and plates always remain united slightly.

[†] It would be useful to perform experiments on very large masses of glass, dropped into water when in fusion. —Dolomieu observed large balls in the lavas of Etna.

the structure of the Causeway, there are other circumstances to be mentioned.

In the glass-house scoriæ connected with the bottom of the melting pots, the following appearance is very commonly observed. The stony slag below the glass has formed into spherical masses, often an inch in diameter, and presenting a structure radiated from a centre, exactly like the Causeway joints *.

These appearances were in 1804 made accidentally the subject of examination by Mr Watt, in consequence of an experiment which he made in order to illustrate, on a large scale, the change of melted basalt into a stony substance. In an admirable paper † he has given a minute relation of the appearances, describing the tendency to arrangement seen in various stages of the consolidating or crystallizing process.

This

---

* I collected specimens of this kind in 1811, to illustrate Sir James Hall's paper on the effects of slow cooling.

† Philos. Trans. 1804, p. 282.

This regular arrangement is first developed in the formation of small spherical globules which are disseminated thickly through the glass formed by the fusion of basalt; this glass surrounds them; and they appear in it, with surfaces touching, like a cluster of seeds of about a line or less in diameter. As they cool, they adapt their form to their situation, filling up the interstices, and presenting a mass which is neither like glass nor basalt.

Such is the case in a rapid cooling; but in a slower mode, larger spheroids, having centres of formation more remote from each other, and often of two inches diameter, are formed, which, as before, are limited in size, by the confinement arising from contact of their surfaces. The structure of each is radiated, with distinct fibres, which often divide at equal distances from the centre, so as to detach portions of a spheroid in concentric coats*. No spheroid

penetrates

---

* Compare Mr Watt's experiments in 1804 with the following general assertion:

" Fossils

penetrates another in contact with it; both compress each other, and have their limits defined by a plane where separation takes place easily. Several spheroids, touching on the same level, are formed by mutual pressure, into pretty regular prisms, with perfectly defined divisions; and when a spheroid is surrounded on all sides by others, it is compressed into an irregular polyhedron.

In the next stage of cooling, the fibrous texture is supplanted by a compact nucleus, which, advancing from the centre, fills the spheroids, and gives the compact texture. In this, as the cooling continues, a granular appearance becomes distinct, and imbedded crystals appear.

I shall not follow Mr Watt into his explanation of these appearances, dependent, in his opinion, on the laws of heat and magnetism;

nor

" Fossils having foliated, radiated, or fibrous fractures, are most unquestionably formed by precipitation from a state of chemical solution."—(Jameson's Geognosy, 1808, p. 38.)

nor into the very probable mechanical theory of crystallization*, which he has offered as the best hypothesis; but proceed to state the application of the facts which he has observed so accurately.

He notices the decomposition of granite in globular forms, called by Werner *distinct concretions* †; and he shews how prismatic configurations of basaltic columns, and their joints, would arise from a mass of fluid basalt. In this manner, he accounts for their actual formation, and for the horizontal position of basaltic prisms in whin dykes, from the cooling influence coming on with equal force from each side [*]. He acknowledges that he is unacquainted with the extraction of spheres from the joints of basaltic columns, and mentions that subsequent observations may confer on his hypothesis all the demonstration of which it is susceptible [†].

---

* Philos. Trans., 1804, p. 291.

† The well known orbicular syenite or granite of Corsica may be described here. It has a minute and confused basis of quartz, felspar, and hornblende, in which are placed touching spheres of two inches across, which are composed of concentric coats of quartz and hornblende. In general, the centre is occupied by hornblende, and surrounded by a zone of quartz. The finest specimens I have seen are at the collection in *La Monnoye*, in Paris. In some unstratified granites, the mica is inclosed in nests or nodules of two or three inches diameter, and having their plates concentrically disposed.

By a happy generalization, Mr Watt has gone farther, and has shewn that the same formation is equally seen in minerals, of which the origin is undoubtedly aqueous, as the calcareous stalactites, of which so many columns are concentric and fibrous at first, and afterwards become sparry; and, in the well known limestones of Sunderland, which are radiated spheroids, often compact in the heart, often with the radii obliterated, and the concentric structure alone remaining. These graduate into the oolites and pisolites, and into perfectly compact limestone, and are illustrated by that view of crystallization which I have mentioned above.

---

[*] Philos. Trans. p. 309.

[†] Ibid.

If I may be allowed, in the present state of the inquiry, to state the connection which exists between many minerals, and their radiated and concentric forms, I believe that it will be found chiefly in the nature of the mineral substance itself.

By the aid of the mechanical dissection of minerals developed by Haüy, we have arrived at the knowledge of the forms of those particles between which the attraction of cohesion is immediately exerted. The simplicity of the results of crystallographical science is conformable to every principle which we observe in nature, where all is complicated in the details, and simple in the means. More lately, Dr Wollaston has shewn, that all the primary forms of minerals, may be constituted of spherical or spheroidal particles *; and an hypothesis, chiefly arising from the nature of mathematical

---

* On the Elementary Particles of certain Crystals, Phil. Trans. 1813, p. 51.

tical figures, has received a great certainty from the researches of MR DANIEL, who has found differences of specific gravity existing in different parts of the same crystal, as in the tetraedrons and octaedrons of fluor-spar, in which a difference might be expected *a priori*, from the variation in the numbers of spherical particles which join to form these figures under equal bulks*.

If cohesion in solid bodies be supposed to arise from the mode of aggregation of crystalline forms, and if fluidity be the result of the alteration of these regular figures into the spherical particles of which they consist, by withdrawing a part of the cohesive power †; and if, as has been satisfactorily shewn, a simplicity of form of crystal accompanies in minerals a simplicity of chemical composition *; it may be inferred, that the more compound the structure of the mass, the less simple will be its mode of arrangement; and that after a certain complexity of chemical nature predominates in a mineral, no regular arrangement of mathematical solid forms will arise in its substance.

---

* See Journ. of Science and Art, N° 7. p. 30.

† This has been long the most probable cause of increase of bulk in all fluids which crystallise in cooling; as in the expansion of water in ice, in sulphur, cast iron, sulphat of lime, &c. An arrangement of crystalline forms appears always to occupy more space than the same quantity of matter in the fluid state.

All the solid matter of the Globe is either capable or incapable of a regular crystallization. We observe in nature many species of minerals well defined, and it is the object of the improvers of Mineralogy, like Haüy and Wollaston, to reduce the pure types of these substances under regular crystallographical arrangements; and it will

---

* We have now at least three modes of ascertaining the nature of bodies, more or less particularly;—chemical analysis, refractive power as to light, and the examination of the crystalline form. In the last case, sulphuret of lead, common salt, fluat of lime, and bodies of not very compound natures like them, crystallise in the simplest forms; others of more elements, as carbonate of lime, in forms more complicated.

will be the business of the chemist to include them under that doctrine of definite proportions which is now forming the basis of his science.—Nature also exhibits to us, in the great masses of the globe, substances possessed of a far more complex nature; for granitic and basaltic rocks, consist, as we have seen, of numerous fragments of the crystals of simple minerals. We might, therefore, be led to infer, that these rocks will not exhibit in their masses any signs of so regular a crystallization as those of the simpler minerals whose crystals they always inclose. On the other hand, we may say, that in proportion to their mixed character will be the tendency to a partial crystallization of the whole mass. Now this is exactly what we find in nature. I have made use of glass in drawing this conclusion, because glass, in complexity of nature, approaches to many rocks; and since it has been shewn, that the tendency of glass is to crystallize in spherical forms. As granite and basalt when unstratified, present the same globular and concentrically radiated structures; as lavas often unfold it; as limestones contaminated with siliceous or foreign matter present it, we are thus enabled to connect the whole of these bodies in one simple structure and origin *.

In fine, in all these examples of concentric and radiated structure observed in the great masses of the globe, I have thus been led to the conclusion, that their identity of structure arises from

---

* The polyhedral concretions of the Cheshire rock-salt have been described by Mr Playfair (§ 34.), and afford another instance of a similar formation. Dr Holland (Geol. Trans. I. 55.) mentions the perfect line of division which exists between the rock-salt and the clay.—The argument for igneous formation is here sufficiently established, from the fact, that water could not be supposed to precipitate the salt, but heat is sufficiently effective to expel the former, and fuse the latter.

The salt at Cardonna in Spain, has a highly crystalline fracture, and is very compact and pure; its large granular distinct concretions fill a valley, (Dr Trail, II. 406.); and Mr Cordier has mentioned that it has colourless grains, and grains coloured from grey to reddish-brown.—(Journal of Science, No. III. p. 154.)

The pumice in the Campo Bianco in Lipari, has a similar structure in globular concretions.

from one general fact; that when in a fluid state a simple mineral can return to its mathematical form of crystal, while a compound rock cannot return but partially. If we seek for the cause of this phænomenon, it may most probably be found in that tendency to mechanical arrangement which appears, as far as we know at present, to be the governing principle of crystallization, and at least offers to our view all its effects in the structure of crystals *. The nature of the passage from the fluid to the solid state, must also modify the forming arrangement of particles; for Dr Brewster's admirable discoveries have shewn, that the crystalline texture exists in glass when it continues in the fluid state. He has also proved, that mechanical compression and dilatation produce such a degree of crystallization in glass as is effectual in polarising

---

* Professor Morichini's discovery of the power of the violet rays of the sun's light in magnetising needles, has lately been confirmed, and may be connected with that influence of light which has been long observed in crystallizations.

polarising light[*]. This principle may have its effect, as well as the rapidity of cooling[†], and the changes induced by the formation of new crystals in the mass of rock, deriving their materials from its substance. The existence of appearances of this kind, to a greater or smaller extent, is an additional fact whence the truth of the general conclusion may be deduced. In other cases, marks of a regular and a spherical arrangement occur in the same crystal, as in the mineral denominated Pearl-spar, where curvilinear forms are given to the rhomboidal crystals, of which the complexity of its constitution thus forms the best explanation[‡].

---

[*] Philos. Trans. 1816, p. 156.—By examining several minerals, when heated, as to their polarising powers, new conclusions may be deduced.

[†] The columns of the Causeway, it is probable from these views, owe their superior regularity and equality of joints, to the preservation of their uniform substance, by a more rapid cooling than the larger pillars around them were subjected to.

[‡] Pearl-spar is composed of lime 29.97, Magnesia 21.14, Carbonic acid 44.6, Iron 3.4, and Manganese 3.5.

In all that has been stated on this subject *, let it be remembered, that every thing applies equally to aqueous or igneous consolidation, and that in fact we need not look into these appearances for proofs of the origin of minerals from either of these causes. For, as has been stated formerly, the true *nature* of aqueous does not differ from that of igneous formation, and we cannot therefore be expected to trace any difference in their results. With regard to Basaltic rocks, there are not, however, wanting other proofs of the peculiar marks of heat, which I now proceed to trace.

---

* I have often observed the regularity of the spherules which are projected from mixtures of oil of turpentine and nitric acid, and which formed suddenly, and when heated, exhibit, when dry, a regular concentric structure in many cases.

The mamillated surfaces of many minerals, as hæmatite, prehnite, &c. are always associated with a radiated structure; and Mr Daniel, by immersing polished carnelian in fluoric acid, found in its dissection, in this mode, a concentric structure, entirely unseen before, (Journal of Science, No. 4. p. 278.)......This interesting fact seems, with others, to render the above appearance general, and may allow us to trace a relation between the crystallising forces, and the external aspect of many minerals. It connects chalcedony, which is always an uncrystallised substance, with the identity of constitution seen in basalt.

7. *Position.* Trap rocks, unstratified, form the highest and the lowest visible rocks, in the countries where they occur; and they even approach in elevation to many mountains of primary chains. They interfere with all rocks, from the oldest primary, to the latest secondary of gypsum and clay.

Since this position will be doubted, and since the latest mineralogical surveys of a basaltic * country, like Antrim, always represent the trap as resting on the uppermost strata of chalk and clay, and forming a cap above them of variable thickness, I shall enter here into some detail.

In the county of Antrim, there are many opportunities of observing that the basalt occupies the highest and the lowest place among the stratified rocks. It forms the summit of every hill and mountain, like granite in a primary tract. Though mantle-shaped strata are not seen resting on its sides, as on granite rocks, yet other appearances equally satisfactory may be observed. On Knocklead mountain, in Antrim, near Ballycastle, I found strata of mica-slate inclined towards the mountain, and, though I could not trace the junction, evidently, from position, resting on the basalt which appears above them*. In a cave on the sea-shore, at Lorryban near Ballintoy, I observed the basalt both above and below the limestone strata. I examined the large nodule of basalt which is imbedded in the chalk near the western extremity of the White Rocks †, and I found several others of the same sort on that coast. At Kenbaan, the chalk is seen forming a mass with basalt above and below it; and assuming at one extremity such a curvature as would naturally result from lateral pressure; while at the other end it is rent and shattered in all directions, the basaltic matter insinuating itself into the fissures and changing the chalk into granular marble at the contact. Fragments of the chalk, of all sizes, appear to have been forced upwards and imbedded in the basaltic rock, having been altered on their surfaces wherever they came in contact with it *.

---

* See Dr Berger, and the Rev. W. Conybeare, in Geol. Trans. III.

---

* This mica-slate is in several spots highly coloured with reddish tinges, and in most places is very shivery, and not coherent. These may be regarded as marks of heat, from the basalt below. The best appearances are seen in the principal burn or ravine on the western side of the mountain.

† Mr Conybeare, in Geol. Trans. III. p. 212.

These

---

* Ibid. p. 209.—Mr Conybeare has given as accurate a description of Kenbaan, as the state of the debris allows of; but his drawings only give an inadequate representation of this interesting spot.——The alteration of the flints there is remarkable.

The masses of chalk here inclosed in the basalt, are analogous to the imbedded masses of sandstone in the greenstone of Salisbury Crags, near Edinburgh, described by Mr Allan, Edin. Trans. VI. p. 431.

Mr Conybeare, in a note, p. 208. supports the igneous origin of Basalt from Kenbaan.

These appearances are utterly inexplicable on any hypothesis but one,—that of the basalt being the lowest as well as the highest rock; and of having been forced upwards, so as to derange the strata of chalk, inclose masses of it in its own substance; and propel or deposit rounded nodules into the chalk, when in a soft state, from the presence of the water which arranged it in layers.

The principal spots in Antrim, where basaltic hills are nearly surrounded with the chalk strata, are the Mountain Devis, the Squire's Hill, the Cave Hill, and the Knocka. In Colinglen, between Colin Mountain and Devis, and along the eastern sides of the whole range, for fourteen miles, the chalk skirts their sides, and appears in many quarries and in numerous ravines. As we penetrate the small glens between the hills, we observe the chalk resting on *mulatto*, (a mixture of it with specks of green earth, or a calcareous sandstone,) and that on the *lias* or slaty blue clay, sometimes inclosing gypsum. The whole series, from its organic remains, and its position, and nature, has been

completely

completely identified with the English strata; the only difference arising in the hardness of the chalk, which is superior, in many places, to that of ordinary limestone*. With this hardness, rents or fissures, not so distinct in the English chalk, are associated, and these are frequently lined with coverings of crystals of calcareous spar.—The whole of the strata of chalk, blue clay, and mulatto, are crowded with shells.

The opportunities of observing junctions are numerous, along the face of the hills; in Colin Glen; at a cascade on the Mile Water, near its rise, on the west side of the Cave Hill; and at some fine waterfalls in Woodburn, two miles above Carrickfergus.

The strata of chalk, except where disturbed, are very regular. The line of their junction

---

* Dr Berger, in Geol. Trans. III. 167. & 130.—The fissures, the lining of calcareous-spar over their surfaces in many places, and the altered aspects in the flints, have appeared to me to constitute, together with the hardness, the principal differences between the Antrim and the English chalk.

tion with the basalt, along the faces of the hills, is not horizontal, but extremely irregular,—a circumstance which may be explained on either theory. A general direction of dip does not exist among them; for they always dip towards the mountains; and, of course, in going round these, they dip towards all points of the compass*. The angle of their dip, thus always at right angles to the side of the hill, is pretty regularly about 9 and 10 degrees.

On Knocklead mountain, the arrangement is completely seen. A zone of chalk nearly encircles its middle region; above which the unstratified basaltic cone rises, and the angle of dip of the chalk is very small †.

Now these appearances are exactly the same with those observed in mantle-shaped strata around granitic mountains, with one exception, that

---

* Dr Richardson had inferred, (Ph. Trans. 1808, p. 214.) that the chalk strata below the basalt is not an accurate plane, but rather resembles a bason, since everywhere, at its periphery, it dips considerably.

† Berger, p. 175.

that the chalk strata, instead of resting on, dip under the incumbent basalt.

The basaltic rock, like granite, forms the summits of the hills; but that it is also the lowest visible rock, is evident from the whin-dykes, which are continuations of their substance, pass through all the strata of chalk and clay; appear on the sea-shore at a great distance below the level of the chalk; and even traverse the bed of the Lough of Belfast. From the Carrickfergus shore to the opposite coast, several whin-dykes appear to be distinctly continued across the bed of the sea,—a distance of three miles; for the same dykes may be traced to correspond at Macedon and Holywood. That these dykes are continued into the basaltic hills themselves, is in many places evident, from their extent and bearings, though, from their number, it is not easy to trace to the precipices the same dyke. The whin-dykes below Ballintoy, and in other spots, are in a similar situation. No convergence appears in them; and no termination to any one *below* is known.

On the hypothesis of a deposit from *above*, it is impossible to explain these appearances, or even that of the occurrence of one rounded mass of basalt in the chalk. To the disciples of Werner it is peculiarly difficult; because it supposes that this great formation of basalt, the newest of all formations, was let fall from a chemical solution in a liquid, which must have retained its matter dissolved during the periods when it acted as a sea, in which many successive generations of shell-fish had lived *.

Why should we then, from the appearances which have been described, refuse to associate basalt with granite? On the theory of an origin from below, all the phænomena meet with an explanation of great simplicity. An unconformable and unstratified rock † lies above and below

---

* The common apparent situation of basaltic masses forming the tops of hills, has been hitherto a strong argument against igneous origin.—See Daubuisson on Basalt.

† I may perhaps be referred here to a drawing given by Dr Richardson in Irish Trans. vol. ix. 48. as a correct representation

low a series of strata. The dykes which proceed from its substance traverse them all; and are evidently, in this respect, related to granite veins. Strata of a substance completely identified with those of the same rock extending over a great part of England and France, differ from them only in possessing a far greater hardness. —Even the numerous degrees of this hardness, indicate the operation of a power acting unequally over extended masses. The direction and dip of the strata confirm the theory of formation from below. Let us conceive a dense mass of basaltic rock raised from the bed of the ocean, and under its waters *. Its heated mass would

---

presentation of the stratification of the precipice of the Cave Hill. In the print, a very regular arrangement of strata is indeed represented. Nothing of that kind is however to be seen on the hill; and as a general view of the spot, Dr Richardson's has certainly the least possible resemblance to the scene. Some of the rest of that gentleman's drawings possess very considerable accuracy.

* The soda of basaltic rocks shews a relation between it and the present sea.

would begin to harden the chalk strata above it; and, after its elevation, its weight of substance would, at the extremities where it overflowed, press down the strata of the yielding substances all around, and present their direction and dip as we now see them *.

Instances of the overflowing of Granite have not yet been discovered, or, as far as I know, been described with sufficient accuracy to enable us to draw just conclusions. Instances of the overflowing of basalt are numerous, and they seem to constitute a principal difference between it and the older rock.

In several spots I have noticed, that the pressure of the mass above seems to have been the cause of the dislocation of the strata. Kenbaan has been already described. At the promontory

---

* Dr Macknight, in his description of Ravensheugh, in Wern. Trans. II. 407. has adopted a similar explanation with this which I have here given from the appearances of the Antrim strata. He illustrates it by a sketch, p. 408. and adduces it to explain a cotemporaneous and aqueous formation; but I believe it to be one of those appearances which result from *pressure* alone.

montory called the *Whitehead*, near Isle Magee, the waves expose the strata of chalk, dipping, as usual, inwards from the shore. A large mass of basalt rests upon them, formed into pillars of considerable regularity. This mass, where it is thickest, seems, from its great weight, to have deranged the strata below by producing a fissure, on each side of which the chalk dips in the direction which could alone be given to it by the pressure of an incumbent mass.—In other instances, the pressure of the basalt has been resisted with great uniformity, as around the mountain Knocklead.

It does not appear that the *debacle* from basalt has been on so extended a scale as that from primary chains*. Every thing indicates that this rock had arisen under a sea not deeper than that

---

* Dr Berger infers, that no disturbance, but wearing down, has occurred since whin-dykes were formed, vol. III. p. 232. He extends the same conclusion to the mountains which they intersect.

Dr

that which washes our present land. In Antrim the chalk presents a position nearly analogous to the boundary of the present shores[*]. Basalt does not graduate into a series of rocks like granite. In many spots, the strata which it forms above the unstratified masses, evidently present an aggregation of conglomerate or rolled rock. Much of this appearance is seen on the cliffs near Dunluce and Kenbaan. Where a complete disintegration of the stone took place, under water, the formation of a fine clay might be expected; and in a clay abounding in oxide of iron, the subsequent heating of the mass would

---

Dr Richardson, in Philos. Trans. 1808, p. 222. has written largely on the debacle from basalt, and infers, with great probability, that all the coast and county of Antrim has been modelled by the wearing down of that rock.

[*] The Rev. Mr Conybeare thinks that the sea and Lough Neagh have received the debris of the Antrim debacle.—Geol. Trans. III. 132.

In Berger's map of the County of Antrim, in the same volume, it will be seen, how nearly the distribution of the chalk is related to the present shore of the country.

would call forth that red colour which all such clays present when heated, from a change in the oxidation of their iron. Strata of this clay interposed between strata of consolidated amorphous or columnar basalt, might be expected to appear. They would exist in all states of hardness, and the presence of steam, as formerly mentioned, might preserve a great softness in some of their beds. In others, the application of a greater heat would fuse the substance completely, and give to it the greatest induration of which it is susceptible. Stratified beds or layers of such clay, and of basaltic conglomerates and amygdaloidal masses, would thus be accounted for in the same manner as the formation of gneiss or mica-slate in the primary mountains. One general principle, disintegration under water, united to consolidation by heat, would attest the simplicity of the operations of Nature.

The appearances here are exactly what have been inferred from the above considerations. The *red ochre*, *bole*, or *iron-clay*, accompanies the basalt wherever it occurs stratified;

where the rock is decidedly unstratified, I have never been able to trace it but in very small quantity. The arrangement of eighteen successive strata at Pleskin has been often described; of these eight are red ochre, in beds of very variable thickness. The same rock accompanies the stratified basalt of the coast for seventy miles. It possesses every variety of hardness. No inclosed mineral is found in the basalt, which is not found in it. I have constantly noticed that where it is thickest, the hardness is least*; where it is thinner, greater. On the cliffs of the Black Head, at Isle Magee, I found all the above principles confirmed by an appearance which I have not seen any where else in such perfection. There the red clay, hardened to a jaspery consistence, and highly splintery, forms, at the entrance of the two caves of the promontory, a lining to the concretions of basalt,

---

* Lest this should be ascribed to the effects of wearing, I may mention, that in Port Royston and Port na Spania, I examined the ochre to some depth, under the exposed surface.

salt, each mass of which is completely surrounded by a covering of it, of two or three inches in thickness. *

I have thus endeavoured to trace the facts which are connected with the *position* of basalt, and the circumstances in which this agrees with and differs from granite. A question may arise

as

---

* Dr Richardson constantly mentions the red clay as *ochrous basalt*, and has given very accurate descriptions of its strata in Edin. Trans. vol. v. p. 20.

" 1. The ochrous strata are extensive, (varying from an " inch to twenty-four feet in thickness); they remain al- " ways parallel to the basalt strata which they separate; " they unite to the basalt, without interrupting its solidity; " the change from the one to the other is sudden, and the " lines of demarcation are distinct. The ochrous stone is " never found but contiguous to the other basalt.

" 2. The substances imbeded in the ochrous rock, and in " basalts, are the same exactly; calcareous-spar, zeolite, " chalcedony, &c.

" 3. Among the varieties which this rock presents, there " may be found every intermediate stage, between sound " basalt and perfect ochre. The change is often partial, " beginning with veins, and slender ramifications."

From

as to the relative æras of these two great formations. This is answered by considering, that basalt must be newer than the strata of shells through which it rises, and which exhibit to us the ancient bed of the sea. It must also be newer than granite, from three facts;—its valleys and debacle and subsidiary strata are upon a far smaller scale; it has risen through strata of mica-slate, conglomerate, and ancient alluvial strata; and its dykes often traverse granite itself*.

8. *Whin-*

From these facts, Dr Richardson has constantly inferred, that this substance is merely basalt in a certain state of decomposition. Irish Trans. x. 92. and ix. 458.—So also did St Fond.

Daubuisson found in Auvergne pitchstone decomposed and reduced partly to a brownish mass, resembling iron-ochre.

Analysis of the Iron-clay of the Causeway,......Silex 31; Alumina 22; Lime 4.5; Oxide of Iron 25; Water 15; Soda none.—(*Dr Da Costa*, Journal of Science, No. 7. 160.)

* That is, newer granite. In the oldest granite mountains, with mantle-shaped strata, no whin-dykes have yet been found.

8. *Whin-dykes.*—The phænomena of whin-dykes confirm the proofs which have been given of the igneous origin of the trap-rocks. They have been frequently described; and new accounts of them, in all countries, are rapidly accumulating. In their structure and nature, a great uniformity prevails. The greater number are simple fissures, filled with substance at a period either simultaneous with, or immediately after their formation. Dr Berger has stated*, that, on the average, he found the widest dykes in primary, and the narrowest in secondary country. In Ireland he has shewn, that a general direction from S. E. to N. W. appears

---

found. In Mull, Jameson has described (Mineralogy of the Scottish Isles, vol. I. p. 220.) extensive basaltic veins in granite, with pieces of granite included in the basalt veins, and in one instance, the granite which bounds the side of the vein mixing with the basalt.

* Geol. Trans. vol. III. p. 227.

appears to prevail in the greater number[*];—a remarkable fact, should it be well established by observations in other parts of the globe, since it connects them with the extended changes which have taken place over the earth's surface, and thus affords a new proof of their origin from the largest masses which compose it. All whin-dykes are vertical, or nearly so. No convergence appears in them; they exhibit no branches or strings; but they are sometimes waved or bent in their course[†]. The nature of the rock which they contain, is of considerable uniformity, at whatever distances they are placed. In the arrangement of their contents, the greater number are of simple, but many of compound structure. In simple dykes, the fissure is filled most commonly with small basaltic prisms, either in an upright or an horizontal position. In most cases, these pillars, if they traverse basaltic rocks, are of a finer grain than the penetrated rock. In other cases, the dyke is filled with amorphous pieces of rock, often rounded. In compound dykes, the sides are often constituted of layers of prisms, upright or horizontal; while the middle is filled by amorphous basalt, or by prisms of larger size than those of the sides *. Although in dykes a considerable regularity of disposition of their contents is thus seen, yet they never present the numerous successions of layers, and the drusy cavities, which are seen in metallic veins.

---

[*] Geol. Trans. vol. III. p. 224. where there is a table of the dykes of the north of Ireland.

[†] I have only observed this circumstance in narrow dykes, when nearly terminating in the uppermost strata.

Dykes are often extremely numerous; and, in many cases, they produce very little disturbance in the regularity of the strata which they traverse;

---

* Mr Wynch (Geol. Trans. vol. IV. pl. 4.) gives a figure of a dyke in the coal near Newcastle, where the sides are occupied by basalt, and the middle by confused fragments of the coal strata, and balls of basaltic tufa.

Dr MacCulloch has described a compound dyke at Strathaird in Sky.—Geol. Trans. vol. III. plate 4.

sometimes none*. From this and other appearances, *three* kinds of them may be well established.

(I.) The first kind is a simple fissure in the strata, formed previous to the irruption of its contents, and not produced by it. The rapid contraction of a wet paste incumbent on heated masses, would give rise to them, and matter from below might afterwards rise and consolidate in them.

(II.) In another kind, the fissure, or a part of it, has been produced by the irruptive power of the ascending matter. In dykes of this kind, the chief disturbances of the strata are observed†.

(III.)

---

[*] Dr MacCulloch (vol. III. p. 77.) has described many dykes in Sky, which traverse the strata with almost no disturbance. At Strathaird (p. 81.) they are so numerous in a small space, that he infers that the undisturbed sandstone must have undergone a lateral extension, equal to at least one-tenth of its substance.

[†] Masses of the rocks of the sides are often found inclosed in the midst of the whin. See Allan on the Vicinity of

(iii.) There are dykes which have consolidated in the rock of basalt around them, nearly at the same time with its own consolidation, as is evident from the imperceptible mode in which the substances are united at the junctions *.

It is obvious, that the last kind can only be seen in basalt itself.—All these kinds present, on wearing down, well known appearances. Being always harder or softer than the strata, they either remain as walls, after the rocks around them have submitted to waste and decay; or they themselves are first carried off, and thus on the sea-shores often give rise to the formation of caves.

From

---

of Edinburgh, Edin. Trans. vol. vi. p. 452—460.—Geol. Trans. vol. iv. plate 28.

* At Fairhead, about half a mile from the highest summit, I saw good examples of this kind of dyke, near the shores of a small lake mentioned by Mr Conybeare, p. 206. and where I saw no basaltic cliffs surrounding the banks.—I endeavoured to trace one of these dykes to the Grey Man's Path on the precipice, which I found to be a true dyke, but was not successful.

. . . . From the nature and the structure of these dykes, taken in connection with other facts, we may infer their consolidation from the action of heat. And, as they pass through all the strata, this opinion will be confirmed by the appearances which they present at their junctions with various kinds of rocks.

. . . .

9. These phænomena have been frequently described; and they supplied one of the first and the best proofs of Dr Hutton, in favour of an igneous consolidation of the strata.—When sandstone is the rock traversed, it is often changed in colour, and hardened; or it splits easily into thin plates *. Mica-slate, when adjacent to the walls of a dyke, has its texture loosened, and its substance reduced to dust †. The charring

---

* As at Salisbury Crags.—See Dr MacCulloch's very accurate account of the junction of trap and sandstone at Stirling Castle.—(Geol. Trans. II. p. 306.)

† In Donegall.—Described by Dr Berger in Geol. Trans. III. 230.

ring of coal in their vicinity was first observed by Hutton; and it forms one of the most common appearances in those coal-mines where dykes traverse the strata*. In Easdale, the clay-slate is shivery where the dykes traverse it †. Slaggy or melted appearances often cover the sides of the trap veins ‡. Red sandstone is changed, in some cases, to a compact hornstone §. Slate-clay is altered to a flinty slate ||. Common clay is hardened to some distance from the rock, and changed to a splintery fracture ¶.

When

---

* Playfair's Illustrations, § 68. & § 267.—As at Saltcoats, in Ayrshire; at the Walker colliery, Newcastle.—See Mr Winch's description of it in Geol. Trans. vol. IV. plate 3.—At the Ballycastle mines, it is reduced to cinders.—(Mr Conybeare, ib. p. 206.) See Mr Aikin on a Bed of a Trap in Staffordshire, vol. III. p. 255.

† Observed by Professor Jameson, Min. of Scottish Isles, vol. I. p. 194.

‡ See Mr Allan, in Ed. Trans. vol. VI. p. 422.

§ Rev. W. Conybeare, in Geol. Trans. III. 201.

|| Ib. p. 205.

¶ Observed on Devis Mountain, near Belfast; and on the Falls river below, near Mr Stevenson's, &c.

—When chalk is traversed, a limestone more or less granular, and generally phosphorescent, is produced [*]. When limestone is cut through, it is seen much fuller of joints near the dyke, than at a distance from it, and more hardened; sometimes tending to the sparry texture of crystallized carbonate, and sometimes enclosing iron pyrites [†].

All these are effects of heat, and all can be imitated by artificial fires. The supposition of a consolidating fluid percolating from the dyke through the materials of the sides, will not account for one of these facts, as far as our experiments can guide us [‡]. The action of heat alone interprets the appearances which we observe in Nature, and interprets them all.

---

[*] As at most of the dykes in the chalk strata of Antrim. The flints are also altered. Dr Berger has described the changes with great minuteness and accuracy, Geol. Tr. III. p. 172.

[†] See the description of a dyke in Northumberland, by the Hon. Mr Bennet, in Geol. Tr. IV. 103.

[‡] This is the only Wernerian supposition which I have met with.—See Dr Murray's Comparative View, p. 132.

I have already mentioned the hardening of the chalk over an extensive country, by the presence of basalt. This phænomenon has hitherto been observed only in the county of Antrim; and, as all that country has a basis of this rock, it affords an additional confirmation of the truth of the general conclusion.

11. When wood-coal is found incumbent upon and overlaid by Basaltic columns, appearances similar to those already mentioned may obviously be expected.—Small beds of this variety of coal were discovered at the Causeway, in Port Noffer and Port Ganye about 1815, similar to those which occur at Ballintoy on the same coast. Last year I had an opportunity of examining all the places where the coal and the columns are in contact. The stratum of coal follows the same dip and direction with those of the rest of the strata. At Port Noffer, immediately above the mole of the Causeway, its depth

is about five feet. The columnar basalt at the upper junction forms a well defined and waving line. From an extensive series of specimens, the change from wood little altered to a charred mass mixed with clay and crowded with imperfect augites, may be traced. There is no perfect coal, as we would expect; and no bitumen. The charred appearances are of every shade of white, grey and black hues, exactly as in an ordinary fire.—In some of the excavations at Port Ganye, where the basalt and wood-coal are in contact, the rock has become of light purplish hues, with many black specks of coaly matter disseminated through it, and numerous air-holes lined with a species of soot. The basalt alters with a constant variety of colours in the same specimens, from a bright red to a greyish white.

12. While this altered wood bears marks of origin, perhaps more recent than the æra of the shells in cliffs not far distant, the appearance of *ashes* in another spot in Port Ganye, adds to

the proof*. These ashes or rather cinders, were found lately in small quantity: I traced them on a cliff, where, from the nature of the ground and the debris, an artificial formation could scarcely take place; I found them in loose sandy soil immediately above the basalt, but the state of the cliffs did not allow me to observe their connection. They resemble the brown slags of ordinary furnaces, and are accompanied by small pieces of very hard jasper, which seem to have originated from the red clay.—This proof is not, however, of much importance.

13. From the existence of *shells* in strata

---

* In Auvergne, Daubuisson mentions particularly the blistered surfaces of basaltic summits, and their spongy *scoriæ*, and their mixture with volcanic ashes.—(Journ. de Physique, 1804, p. 47.) He describes lava in the form of currents, basalts, and porphyroid masses.—In the collections of St Fond and Spallanzani, preserved in the Museum of Natural History at Paris, I found many exactly corresponding to Scottish and Irish specimens.

evidently modified by heat, I shall attempt to deduce a proof of more importance. When a shell, as a belemnite, occurs in the crystalline limestone near the junction of a whin-dyke, the texture of the brown limestone which forms the shell becomes considerably more crystalline than in belemnites at a distance; but a more important remark is, that the shell exhibits such a complete union with the mass around it, as could only result from a change which has affected both in the same manner, and which renders it impossible to detach it entire. In some specimens these blending appearances are of great distinctness.

That the rock containing ammonites at Portrush should have ever been mistaken for basalt, in any one of its numerous varieties, is a circumstance to be accounted for only by that remarkable disposition to hypothesis which has so frequently disgraced Geology *. It is the more

---

* Dr Richardson's Siliceous Basalt.—Edin. Trans. vol. v. p. 15. Compare his description with Mr Conybeare's, Geol. Trans.

more singular in this instance, as three alternations of the flinty-slate with the greenstone are constantly before the eye of the observer.—MR CONYBEARE has inferred, with great probability, that it is the altered slate-clay of the lias formation, and I found it closely associated in characters with a soft variety of slate-clay, which is found below the first range of columns at Fairhead. There, and at Portrush and the Skerries, the large-grained greenstone, consisting of felspar and augite, is closely associated with it in unstratified masses to which the slate is conformable *. The shells are ammonites, and present that variety of appearance which we

---

Trans, vol. III. 213. as an example of two of the most opposite accounts of the same rock. After spending two days at Portrush and the Skerries, I could not find one instance of the transition into trap which Dr Richardson mentions. Mr Conybeare has traced its true relations.

* In Cruachan, Rasay, Shiant, Sky, &c. Dr MacCulloch found beds of flinty-slate altered by their contact with trap, and infers that they are common clay-slate and shale hardened.—Geol. Trans. III. 99.

we should expect from the agency of heat. While some are pretty well defined, others form a close union with the slate, and pass into every variety of blending, till at last they become visible only by slight vestiges. The rock in which they lie also presents considerable varieties of induration, and in many places passes into very thin layers. Appearances of this kind are entirely irreconcileable with an aqueous deposit. In shells never altered by heat, as in chalk beds, the forms should be preserved in all their sharpness, for a chemical action cannot be admitted without entirely dissolving them. Heat alone can produce that unequal consolidation of the slate, that separation of thick and thin layers, and those attempts to alter without completely obliterating the form of the shell, which we see exemplified at Portrush so evidently, that no part of the Globe presents more decisive marks of its action.

14. The existence of water in basalt, often occupying small cavities in its substance, was

long adduced as a proof of its origin, till the agency of a compressing force to retain it was established by experiment. But, since lavas do not contain water, it may be inferred that this difference between them and basalt, tends to another proof of the above principles. For lava is erupted in the air, and spreads in thin sheets over the soil, without a sufficient mass to retain in its substance highly condensed steam. Basalt, on the other hand, has flowed below the bed of the sea, of which the pressure would be effectual in retaining water when heated. We should therefore expect, *a priori*, to find water in basalt, and none in the lavas of our present volcanoes.

15. Werner has observed, that the basis of amygdaloidal traps is the coarsest part of the precipitation, and that the vesicles have been filled by the remaining solution, or by a filtrating fluid, which contained a finer solution *.—

---

* Jameson's Geognosy, p. 48.

If, for reasons already given, we withdraw from this passage the ideas of solution, and of a filtrating fluid, of which we have no evidence, we find an exact conformity with observations[*]. The tables of the analysis of minerals exhibit no substance enclosed in basalt, which possesses elements different from those contained in most varieties of that rock.····This is an additional reason for believing in the formation of these inclosed masses of calcareous spar, zeolites, &c.[†] from the substance of the rock itself, as Werner has supposed. It does not indeed afford a proof of aqueous origin, but it offers no obstacle to an igneous formation. And when it is confirmed by the experiments before mentioned, of the formation of such substances in a comparatively short time, and at the present day, we have all the evidence which such an appearance can afford *.

---

[*] See the observations given on Crystallization, *above*, under the Primary Rocks.

[†] Dr MacCulloch has traced the transition from mesotype through chalcedony to chert.—Geol. Trans. vol. III. 87

I have now collected all the evidence which the observations of others and my own have made me acquainted with. The conclusion at which we have arrived, has been indeed drawn for nearly half a century, but from evidence so imperfect, that it could never command universal assent †. Even yet the proofs may not be considered complete by all. As the progress of discovery advances, more may be brought forward;

---

* De Luc *junior* lately maintains anew, that the crystals of all lavas are previously formed, and infusible in it. They should, then, be worn on the edges or angles, and not well defined, as we see them.—(Journ. of Science, No. 3. 158.)

† By the Rev. Mr Hamilton, and others. See St Fond's Travels in Scotland, 2 vols. 1798, where every stone is called a lava. But the distinctions between lavas and basalts, as well as their similarity, cannot be traced too accurately; and some of them have been undoubtedly omitted, from the influence of hypothesis.

ward; and of this progress we are never to despair. The chief proofs of origin upon which the mind may rest are, colour, structure, and the appearances of whin-dykes, shells, and wood-coal. Position offers another evidence of the strongest kind. The general conclusion is, that nature offers to our view, three kinds of unstratified rocks, granite, basalt and lava; that these have had their origin at different æras; that each is associated with a peculiar class of phænomena, and that one common structure belongs to all.

The rocks denominated Transition and Secondary in the System of WERNER, have been long observed to connect, by insensible gradations, with the more primary strata. In them the mechanical aspect, or the deposit in a state of soft mud, has never been doubted, excepting in a few cases*. In this outline it is not at present necessary to treat of them at length. The origin of the greater number of them from the degradation of more primary strata, has been generally admitted, and forms one of the bases of the Wernerian arrangement, where the ancient liquid which dissolved the land, is supposed to have lost by slow degrees its chemical powers, and acted only as a mechanical agent. With the exceptions of coal, rock-salt, and shells, we find no subtances in the secondary which do not exist in the primary strata *. Felspar, the principal constituent of granite, is presented in compact felspar rock, in secondary porphyries, clay-slates, and grey wackes, in various states of comminution

---

* It is remarkable, that as inferences of mechanical appearances have increased in the primary rocks, the tenden-cy

---

cy of the disciples of Werner has been to increase the number of chemically precipitated rocks; and thus conglomerates, sandstones, and grey-wackes, have been all represented as chemical deposits.

Professor Jameson (Geognosy, 39.) terms a sandstone with a quartz cement or basis, a rock partly of mechanical, partly of chemical formation.

* These three deposits are related obviously to arrangements different from those of the older strata.

comminution and consolidation. In sandstone the quartz of granite appears again over extensive tracts. The secondary limestones may have derived their origin from the rocks of the same material which existed in the first masses of land. Gypsum is found occupying beds of considerable extent in the Alps, as well as arranged with clay among the uppermost of the strata *. Where chalk occurs, it gives rise to a very extended and flat country, like much of the south of England, and part of France; and, from the remains which it encloses, it appears most probable, that it is itself, along with them, a deposit from the ocean.

All these secondary strata form far larger tracts than the primary; and the most fertile and cultivated soils are found in them, and in basaltic countries. They do not rise so high on the mountains as the older strata; but the

---

* Gypsum in mica-slate occurs in a bed in the higher Alps, near the Valley of Cogne. It also occurs at the bottom of St Gothard. (Dr Thomson's Chemistry, 1817, iii. 555.) Brochant calls this gypsum Transition.

extent of the surface which they cover, gives rise to a more horizontal arrangement of their beds, than is generally seen in the latter rocks. They are also more numerous in their varieties, and subdivisions; for, in deposits continued over larger surfaces, a greater variety of aspect might be supposed to arise *.

In

---

* Jameson has conjectured, that felspar and clinkstone are nearly allied; and from observations in Arran, Dumfriesshire, and the vicinity of Edinburgh, that clinkstone-porphyry passes into compact felspar and claystone. (Wern. Trans. I. 345.)

Dr MacCulloch has written extensively on grey-wacka, and thinks it impossible to draw any exact line between it and mica-slate. (Grey-wacka consists of altered fragments and grains of different rocks, in a cement or basis of clay-slate.) He thinks it probable that it will be found alternating with mica-slate.—(Geol. Trans. II. 417. 444. and vol. III. 36.) The Mourne Mountains in Ireland, seem to be distinguished from the Grampians of Scotland, by hahaving grey-wacke instead of mica-slate above granite.—(Dr Berger, III. 123.) Jameson has traced in the Pentlands alternations of grey-wacke and secondary clay-slate (Wern. Tr. II. 184.), and so has Mr Horner in Somersetshire, (Geol. Tr. III. 344.)

Dr

In such a fluid as is supposed to have let fall the primary strata, the disturbances which ensued would be sufficient to break into fragments

---

Dr MacCulloch's numerous observations destroy all idea of any line of distinction between primary and transition rocks, all forming a graduating series of one single formation.

In limestone, there are no less singular anomalies to the Wernerian accounts. Dr MacCulloch has described (vol. III. 39.) the marble of Killbride in Sky, as placed between regular beds on one hand, and an irregular surface of unstratified syenite on the other. It is often divided into insular portions, surrounded by syenite, and then loses all semblance of stratification. Though its hardness is very variable, (110.) yet its aspect is quite primary and granular; pure in nature, excepting where it is in contact with the syenite, or with trap veins, when it is overloaded with silex, magnesia, and argilla. Hills of trap surmount it.

At Sleat, in Sky, a bed of shell-limestone is included between two beds of quartz-rock, which alternate with mica-slate. In the same island, quartz-rock alternates with blue limestone and red sandstone, (III. 31.)

All these, and other appearances discovered by the same excellent observer, are entirely hostile to the Wernerian formations. No explanation of them has hitherto been proposed.

ments and disintegrate portions of rocks newly formed, or in the act of depositing. Breccias and conglomerated rocks of rolled pieces might thus have their origin; and the same beds, as in the primary strata, be repeated in successive alternations. Lower and lower levels in the outgoings of the strata would follow, and shew us how closely one principle has acted in giving rise to all the strata of the earth.

" We frequently, (says JAMESON,) observe
" in the same mountain, beds composed in
" small grains alternating with those in large
" grains; but we rarely find such an alterna-
" tion in the same bed; on the contrary, the
" lowest part of the bed contains the largest,
" and the upper part the smallest grains;
" hence such an alternation of beds as that we
" have just described, is not to be considered
" as contrary to the laws of hydrostatics, as has
" been asserted by some *."

The

---

* Geognosy, p. 156.

The appearance of shells in all these strata has given rise to a branch of Geology which has now advanced farther towards perfection than any other part of the science. WERNER first discriminated different formations by the petrifactions which they contain; and gave the name of *transition* to those strata, in which, according to him, they first begin to appear. In England and France, this subject, however, has been studied with far greater attention and minuteness of research, than in Germany. MR SMITH, the author of the geological map of England, was the first to ascertain, in Great Britain, the fossils peculiar to each bed; and, at the same time, unconscious of Werner's theory of formations, to discover the constancy in the order of position and continuity of the secondary strata. The identity of the English and French strata has been since made evident. And those formations which have been, with propriety, termed *Independent*, because they occupy only particular spots approaching to a basin or hollow form, having been correctly described, a coincidence has been established between those of London, Paris, and the Isle of Wight *.

MR PARKINSON concludes the second volume of his excellent work on the Organic Remains of a Former World, by a series of inferences well drawn from the facts observed. He is of opinion, that the shells and corals have not been transported, but have lived and died in the spots where they are now found, and which constituted the ancient bed of the sea; that, while many kinds existed formerly, which we do not find now on our present shores, yet no line of separation is drawn between the creation of extinct and existing species; the former being, in many strata, found along with the latter; and that, from the delicate structure of

many

---

* By MR WEBSTER, (Geol. Trans. II. 161.), whose descriptions connect with those of MM. CUVIER and BRONGNIART, in the environs of Paris.—(See a general view of their discoveries by Professor Jameson, p. 293. 2d edition.)—Mr Parkinson, in Geol. Trans. I. 324.

many of them, compared with the little injury which they have sustained, their solidification was effected, in several instances, before the waters had removed from them*.

Thus in the times that are past, we find that Nature, true to her unity of operation, has acted as at the present day. No blank appears,—no space without existence, by which, like HUTTON, we could infer that the present land had existed as part of a world more ancient than the primary strata. When it is considered how rapidly many species of shell-fish propagate their kinds, farther observations may enable us to connect the appearances which their fossil beds present, with those of more recent formation. We may be even able, in time, to trace relations between the extent of the strata of shells, and those natural chronometers which we find in the quantity of debris around the precipices of the mountains *.

---

* Beds of fresh-water shells having been found below and above those of marine shells, by MM. Cuvier and Brongniart, in the vicinity of Paris, it has been shewn by M. Beudant, from experiments, that shell fish, of several fresh-water kinds, may be habituated to salt-water, but that others resist it. Observations also shew, that oysters and muscles often proceed pretty high up in rivers.—Cuvier's Analysis of the Labours of the Institute of France for 1816, in Thomson's Annals, vol. x. p. 143.

On this subject, we again find a mark of correspondence between the best inferences drawn from petrifactions, and the ideas given above of the origin of the strata. There being only *one* general formation of all stratified rocks in the same manner, only one formation of shells found along with them, should be expected,

---

* The rolled masses below a cliff, or on the side of a hill, exhibit, by their quantity, the action of a period of time far from ascending to very remote æras: Thus, at Salisbury Crags, (see Jameson, in Cuvier's Essay, 200.)—Cuvier has connected appearances of this kind with the extent of alluvial land formed on several coasts, with the quantity of sand which has sometimes overblown considerable tracts, and with the extent of coral reefs. These shew, that no very long period of time has elapsed; but observations of this kind must be always more or less imperfect, from the want of exact and remote historical evidence.

pected. This is Mr PARKINSON's conclusion; and it appears to be most consonant to all the phænomena yet observed.—No shell has yet been traced in granite or trap; but beds of limestone, containing shells, have been found resting on both rocks *.

---

* On no subject have some popular writers descanted more, than on the time required to form a petrifaction, or to remove the organic matter, and substitute in its room limestone or flint. The process by which this can be done, on any probable supposition, has been already explained, as far as our present knowledge appears to admit of. The appearances of many specimens shew us, that so far from being a slow, petrifaction may be a very rapid process. In the Cumberland mines, the square wooden spouts are completely impregnated with a calcareous stalactite in about twenty years. In those specimens of petrified coral-rock which are brought from the island of Antigua, we have often, in four inches square, unchanged coral at one end, and at the other quartz-crystals, the intermediate space being occupied by the gradation from changing coral to chert, chalcedony (with small druses of quartz-crystals), and quartz. Now, in this case, may it not be inferred, from the analogy of many other examples, that had the petrifying process been a slow change, it would have gone on pretty uniformly, within a space so small as four inches, and not have presented

Though carbon is said to be found in some traps, and though it has been discovered lately occupying,

---

sented transitions so rapid, as the passage from chert to quartz? Whereas a rapid alteration might be easily supposed to produce a rapid transition.

Having given some attention to this subject, and collected many specimens to illustrate it, I was pleased to find this view confirmed by an inspection of perhaps the largest mass of petrified wood in the world. It is a mass of the lower part of the trunk of a tree, lying a mile below Crumlin, in a stream which enters Lough Neagh, about two miles from that village. The specimens of wood from that lake, and its supposed petrifying quality, are well known: the late lamented Mr Tennant found no silex in its waters; and several appearances shew, that the altered woods had been formed at some previous æra.—The surface of the mass alluded to, is about five feet by six; one-half is unchanged in texture, and will burn without flame; one-half is changed to flint of greater or less hardness, in the cavities and surfaces of which, druses of minute quartz-crystals appear. The separation between the changed and unsilicified part is very gradually marked. Here, there is nothing in the position of the mass, nor in its nature, which can explain the partiality of the process. The silicified parts are pretty equally distributed through those that are unaltered. Had

a

occupying, in the form of graphite or plumbago, the place of mica in a primary shistus[*], yet the chief reservoirs of it are limestone and the atmosphere. The proofs of the origin of coal from wood have been frequently collected. The existence of this substance along with a peculiar series of rocks, in *independent* formations, sanctions this idea of its origin[†]. But we find in coal the same principles nearly as in wood; there are mines where the coal is constituted,

---

a slow change, acting for ages, been the cause, the *whole* trunk would have been gradually affected. But in a rapid change, time might only be allowed to silicify a part; and such a rapid formation of siliceous matter in the vegetable structure can alone account for the appearance. The pile of Trajan's bridge over the Danube, said to be partly changed to agate, may be a slower formation; but from all the present appearances, the deposit of flint or limestone in a shell, a bone, or a piece of wood, may be a deposit of the most rapid kind.

[*] In 1816, near Beauley, in Inverness-shire.—The true relations of carbon to trap are still uncertain.

[†] Jameson's Geognosy, p. 180.

stituted of altered trees, with the woody texture remaining[*]; impressions of ferns, reeds, and other plants peculiar to woods, are discovered in the strata near it, or in the sandstone which covers it; and parts of its substance pass into or penetrate the bituminous shistus which is always connected with it. The approaches which are made to coal by the continued action of water on wood in the lower strata of bogs, strengthen these ideas of the nature of its formation[†].

Dr MacCulloch has lately shewn that heat of itself cannot convert wood into coal; that in natural processes water changes it to bitumen, and that jet may by heat be altered to coal. In his experiments, he blackened clay with jet, so as to produce an exact resemblance to bituminous shistus[*].—It is not improbable that the presence of steam, aided by compression, may produce at once that change from wood to coal, to which approaches are seen in the slower agencies of water at the present day.

---

[*] As in the coal of Bovey, near Exeter.

[†] See the account of the submarine forest on the coast of Lincolnshire, in Ph. Trans. 1799, p. 145. and Mr Hatchett's observations on the change of some of the principles of vegetables into bitumen, Philos. Trans. 1804, p. 387. In Geol. Trans. III. 380. Mr Horner describes a submarine forest on the river Parret, in Somersetshire.

---

[*] Geol. Trans. II. 23.

In the denser masses of the globe, the metallic bases of the earths may be thus inferred to exist, mingled with the other metals, sometimes in a more compound, sometimes in a purer state. The presence of water gives rise to a new state of things. Ignited masses of earthy minerals are formed, which we have already spoken of as being chiefly granitic. The general form of our islands, primary mountains, and volcanic hills, exhibits more or less of that conical aspect in which these masses were thrown up*. That water was previously present, is concluded from its being found in all the rocks, from the figure of the Earth, and from all that has been said of the mechanical nature of the strata*. Its steam may assist in elevating these, or more probably, this original formation may be owing to the expansion of the solid materials of the globe from their combination with its oxygen, and the consequent pressure produced on some points of a level and semifluid surface. As the pyramidal and heated masses rose above the waves to a gigantic altitude of many miles, they would be subject to an immediate and most rapid degradation. The waters around them, more fluid from the heat, and more active from the currents which propagate caloric in all warm liquids, would receive the immense debris. The largest fragments of felspar and quartz would be first produced, and soonest consolidated. As the degradation became less rapid, quartz and mica, with less felspar, would form the newer layers of gneiss. Where the mica fell more slowly, mica-slate strata would be deposited. Grains of quartz would accumulate into quartz-rock *. The finer particles of felspar, of a clay aspect, would precipitate in clay-slate. Where a greater heat acted, crystals of felspar would form in the basis, and produce porphyries †. All these strata, deposited on sloping sides of the granitic pyramids, would receive their consolidation in that position, and their mantling shapes and bendings would follow from the inequalities of the surface on which they rested. The heavings of the fused mass below, and the heat which it would preserve, would give rise, in some cases, to new disturbances of the layers already deposited; in

---

* Most writers remark the conical aspect of granite and porphyry mountains. Perhaps the finest view of this kind in Scotland, is that of Ben Nevis, from near Achnacrags, in Mull, at a distance of forty miles from the mountain.

---

* That the water was salt, like that of our present oceans, may be inferred with some probability from the numerous experiments of Sir H. Davy, who, by the Voltaic action, found minute quantities of soda in a great variety of minerals.—Philos. Trans. 1807, p. 10.

---

* It is in the chain of the Ourals that the materials of granite have been distributed on the greatest scale. There, one entire mountain is of quartz, another of talc, a third of felspar.—Pink. Petralogy, I. 148.

† Many porphyries appear to have been formed in this way: many completely fused; as in the instance of veins of porphyry traversing granite.

in others, the strata depositing next the granite, being heated, would, from the expulsion of their water, contract and open in fissures, through the ramifications of which the melted granite rising, would present the irruption of veins in the shistus *. In the state of a wet or heated paste, other masses might, from compression, assume the waving aspect.

These operations, carried on under the waters, would be increased by the rapid disintegration of these slaty rocks, as they were forming. Finer and finer particles would thus be attained, and be carried to greater and greater distances from their original source: Just as the

---

* This explanation connects the *presence* of the granitic veins with the *cause* of the fissures; a circumstance which I am not aware of having been before observed. It also distinguishes granite veins, which are often branched so minutely, and have risen up through strata when depositing, in consequence of fissures made in this mode, (See above, p. 118.), from whin-dykes, where the greenstone has been elevated through fissures that are unbranched and made in strata which had been previously consolidated or arranged.

the outgoings of the strata of clay-slate are more extensive than those of mica-slate; of mica-slate than gneiss. From the disintegration of porphyry and limestone, and the longer suspension and easier degradation of the last rock, many of the secondary strata would gradually fall down. The general direction of all the strata, excepting those immediately enveloping the granite nuclei, would follow from the impulse given by the waters to the matter which they contained, by the action of a general motion of the waters, connected with the rotation of the Globe.—As the cooling of the central mass must go on more slowly from the nature of the envelopes thus produced, a provision would arise for subsequent disturbances, for the origin of basalt in many places above the newest strata, and for its propulsion upwards in dykes, in consequence of its expansion when fused. Those parts where the ignition had continued longest, might at a later æra discharge their basalt and greenstone rocks, and thus present the last change which many countries have undergone from the dominion of fire. In the spots where it still lingered, or where there was a more ready access of water to the metallic nucleus, our present Volcanoes would form their products, either in the air or below the waves, force their way through beds of porphyry and limestone, raise their regular cones, emit their streams and dykes of lava, and present us, after intervals of repose, with operations considerably analogous to those of a more gigantic kind, which had raised the larger masses of continental and insular land.

When we tread, at the present day, the summits of primary mountains of the first order, the sentiment of solitude which fills, and the expanse of the prospect which arrests the soul, gradually give way to the particular examination of the scene. Here is the true theatre of the Science, the fountain of sublime speculations, the connexion of life and mind with grand imagery and impressive views. We stand on peaks of granite, emerging from a dense cone, or on loose blocks piled up in pyramids on the edge of tremendous precipices. All around are ruins. The quartz, which has remained after the decomposition of the felspar, exhibits, in large grains at our feet, the oldest and most indestructible substance of our world, and recalls us to the shores of the ocean, where it is equally abundant, after surviving every change of place *. The larger masses of rock proclaim their descent from a greater elevation; or assume, on level and desart plains, the direction in which they had been left by the last wave which passed over them †. The waters have indeed passed, but have left every where the marks of their overwhelming power. In the distant

ocean,

---

* Mr Jameson (Wern. Trans. I. 109.) asks, "Is it probable that quartz will be found to be the oldest rock of the crust of the Earth?" The consideration of its occurring in every situation, answers this query: in this respect, quartz is peculiar among minerals.

† The mountain Benybourd, in the Forest of Avon (4000 feet), and those larger masses near it, Ben Avon, Ben MacDhui (4300 feet), have several square miles of flat summits, where all the granite slabs have taken positions from the action of water.

ocean, often diminished to a silvery line, we descry the womb of our continents, and perhaps their grave *. A multitude of pyramids appears to range over a vast plain in no certain order †, often losing their summits in thick masses of clouds, and often presenting façades of rock, which are resplendent in the sun-beams. We observe, that on the west they ascend with a gentler slope, and that their eastern and north-eastern sides frequently contain perpendicular precipices of great elevation ‡. As they diminish in height, or fall away gradually or more suddenly into level tracts which extend to the sea, we are led to the consideration of the valleys,

---

* Milton, of Chaos, Par. Lost, II. 911.

† This is the general nature of the view, as it has appeared to many observers in alpine tracts;—to Saussure and others.

‡ Confirmed by many observations. Patrin has noticed the eastern precipices of the Daurian mountains. See Ramond's Travels in the Pyrenees, (p. 10.), where an eastern direction is also seen.

leys, and of the rivers which traverse them *. These present generally marks of a great regularity in their development †. As we begin to trace them, from the pure rill which rises at our feet, fed only by the rains or the melting snows, we observe the first ravines occupied by water, and crowded with masses of rock. These streams, as they descend into glens of considerable inclination, in courses waving in the detail, but straight

---

* That valleys have been formed by the action of water, is a truth so obvious, that it is remarkable to find that it had ever been doubted. The principles of mechanical deposit, and consequent softness, and gradual hardening, afford every explanation of the formation of the great valleys, where every hill bears marks of the action of Water. In a low and flat tract, the present streams are sufficient to penetrate their course; never in a higher country.

† The valleys of the Alps are either longitudinal or transverse: in Jura, most are longitudinal; in the Pyrenees, they are nearly at right angles to the mountain masses. See Journ. des Mines, Nº 126.—In Devonshire, Dr Berger found all the valleys similar, and perpendicular to the mountain-plain of Dartmoor Forest, whence they descend.—Geol. Trans. i. 118.

straight in the general direction, are bordered with the debris of the mountains around; and the slopes of these mountains are often entirely covered with it. We observe, immediately, that the masses of rock, which bear evident marks of having been worn down by water, are too large to have been put in motion by the present streams, and that indeed the largest debris is never seen beyond the higher and more elevated parts of the valleys *. When we follow the river, we find in these alpine valleys, no

---

* Saussure was among the first to make this remark, which is so evident from all observations: " It is an important observation for the theory of the earth, that in the upper parts of valleys, surrounded with high mountains, no rolled pebbles, foreign to the valley itself in which they are met with, are discovered; those observed, are all spoils of the adjoining mountains. In the plains, on the contrary, and at the openings of valleys which adjoin the plains, and even some way up the sides of the mountains which border on these plains, pebbles and blocks are found, which might be said to have fallen from the heavens, so different in their nature are they from every thing found in the environs."—§ 717.

no rolled stones which are not the spoils of the surrounding cliffs. These cliffs often rise with mural precipices, sharp peaks, and rugged scars, which strike the eye at a great distance, and allow us to distinguish the nature of the mountain from its aspect in the landscape. As we gradually emerge from these rocky walls, the slopes become gentler, the openings wider, and the debris more varied. The valleys, now leaving the mantle-shaped strata, are sometimes parallel to the beds of rock, and sometimes cross them, the former being generally the deepest. Large blocks of stone still continue to appear on their sides, of a size by far too great to have been ever put in motion by the present streams, and often placed at a distance from their present banks *, but bearing the deep-worn impressions of

---

* All observers have traced marks of two *debacles* in every valley;—one, from the effects of a larger stream than now rolls in it; the other from the present river....Amongst many appearances of this kind in Scotland, the blocks in the course of Glen Dochart, above Killin, are among the most

of the currents which have channelled them, or of the rocks which, resting upon them, have scooped circular depressions in their substance. The rivers continue to roll forward, often through openings which widen and contract without any apparent order; their waters sometimes expand into lakes, and indicate periods when the outlets of the valley, often narrowed, stood at a higher level than in the present day *; sometimes approaching suddenly to narrow passages in the rocks, they descend in cataracts. When they reach the low country, the debris diminishes in size; and when a tract approaching nearly to a level plain is entered on, they assume

---

most perfect examples.—The alluvial terraces often seen in the courses of rivers, are either referable to the larger stream, or to the presence of ancient lakes. See Jameson, (Wern. Trans. vol. II. 1818, p. 620. *note),* who mentions his not having met with any of these terraces high up on the sides of the valleys of the Grampians.

* Dr MacCulloch has lately published his examination of Glen Roy, distinguished by the minuteness and clearness which give value to all his accounts of geological phænomena.—Geol. Trans. vol. IV.

sume meandering aspects, in curves far more prolonged than when they rolled amid the higher tracts of the mountains *. Frequently rivers traverse plains of this kind for hundreds of miles, amid horizontal strata of clay and sand, without a pebble or a rock in their course, till, like the Ganges or the Orinoco †, they colour to a great distance

---

* The meanders of rivers commence in the sandy plains of the mountains, and are dependent for their number and size entirely on the inclination of the valleys through which they flow. The changes of the Ganges, described by Major Rennell, are seen in miniature on a sea-beach of pure sand, in the channels formed by small streams at the ebbing of the tide.

† See Staunton's Embassy, for an account of the mud of the Yellow River, and its entrance into the Sea of China.—It was from the alteration of colour in the sea, that Columbus, in his third voyage, inferred his approach to the South American continent, before he came in sight of the low land at the mouth of the Orinoco. Dr Nugent (Geol. Trans. I. 75.) expresses his belief in the rivers Orinoco and Amazons having formed all the line of coast, and great extent of country, between their extreme branches. See also Lochead's Observations on Guiana, Edin. Trans. vol. IV. p. 50. for some interesting details on this subject.

distance the waves of the ocean with the immense quantities of finely divided matter which the rapidity of their motion enables them to retain.

What nobler enjoyment arises in the mind than to awaken it to these views! What more delightful task, than to trace, in all the arrangements, the sure marks of a First Cause, acting by regular laws, bringing order and utility out of the apparent elements of chance and confusion, connecting the precipice of the mountain, and the wave of the ocean, in one mutual dependence, and rendering the whole subservient to the existence of that quantity of life and enjoyment, for which all has been contrived!

We trace, on the sides of the mountains, the ascending vapours, and view them condensing in dews and rains, or falling in the evenings, to rest as mists in the deep valleys*. We admire that perpetual circulation of water on our world, which connects the minutest drop that descends, with the fertilisation of the land, and the immensity of the ocean. We endeavour to explore, by the direction of the clouds, the motions of the currents of air which constantly blow over these elevated tracts. We search the summits and the ravines for those rare plants, full of gracefulness and beauty, which alone are able to sustain the lowness of the temperature, and which have never descended into the plains *. In the dispersion of others, and the heights at which

---

* A high mountain tract affords the finest exemplifications of Dr Hutton's admirable theory of rain, from the meeting of currents of air of different temperatures. In some cases

---

cases, the vapour is precipitated so rapidly, that the most extended prospects are obscured almost instantaneously. The dense sea of vapour which then surrounds the observer, concealing or displaying the peaks and precipices near him, gives rise to very noble scenes.

* Dr Wahlenberg has given a most interesting view of the gradual decay of vegetation, on ascending the Lapland Alps, tracing the plants minutely. See Linnæus' Lachesis Lapponica, by Smith, vol. II. p. 272.—282. See Humboldt's late memoirs; and interesting details by Mirbel, in Journal of Science, N° 3. 35.

which some grow *, we find traces of the mountains having afforded the origin of the vegetable tribes, as they have given rise, by their disintegration, to all the low land.—Yet all these, and other pursuits, fade in interest before the sublime scenes and conclusions of Geology. Here we have only to lament deeply, that in a science which will soon rank among the noblest employments of the mind, we as yet trace imperfectly all the laws which have arranged that world which

---

* Willdenow has examined this subject with considerable diligence; but observations are as yet incomplete, (Principles of Botany, 2d edit. 1811, § 354. § 376.) Primary mountains are the richest in plants. Great Britain has the Flora of the North of Europe, Norway, Sweden, and Lapland; but the mountains of Scotland exhibit in their plants a closer connection with Norway, than those of England; and in Cornwall, many plants of the Pyrenees are observed. This subject connects Botany intimately with Geology.—Humboldt's researches on this head are extensive, (*Tableau Physique; Memoir on Isothermal Lines, &c.)* He has shewn how to determine, *a priori,* from the plants and the latitude, the height of the mountain ranges of central Asia. See his tables, in Dr Thomson's Annals, vol. VII. 385.

which has been bestowed on man. The revolutions, the æras, the destroying and creating powers, the awful and sublime appearances; operations not momentary, but acting on the greatest masses, and for ages, equally in the grand and the minute, forming a country, or wearing down the rocks of a waterfall; the preservation of life amid such scenes; all recall the lines of one of the sublimest of Bards, when viewing a most impressive Alpine spot:

> Præsentiorem conspicimus Deum
> Per invias rupes, fera per juga,
> Clivosque præruptos, sonantes
> Inter aquas, nemorumque noctem *.

The great masses of alpine land appear thus to have been formed in separate clusters, and immediately and rapidly disintegrated. The idea of all the great chains of mountains proceeding from

---

* Gray, Ode written at the Grand Chartreuse, near Grenoble.

from N. to S., which was long a favourite speculation of some geologists, has not been confirmed by careful examination: distinct traces of it appear only in some ranges. The first elevations, whence the rest of the land was formed, seem, as far as has been yet observed, frequently to surround each other, without any precise order, exactly as we might suppose from the action of that power which elevated them. The size of the original mountains may, in many cases, be inferred from the extent of the territory connected with them. Thus, in Asia, the central land of the Himmalay and Tibetian mountains has been lately shewn to be the highest on the globe; and Asia is the most continuous of the continents. From volcanic chains, like those of the Andes, the same inference cannot be drawn with propriety.—We do not observe any definite relation between the height of mountains, and their distance from the equator. The Alps are in lat. 45°.; but Mount St Elias, on the N. W. coast of America, in the sixtieth parallel, has been estimated at upwards of 12,000 feet in altitude. More appears to depend upon the nature of the rock, the quantity of its degradation, and the æra of its origin, than upon the relative position of the mountain on the surface of the globe.

Volcanoes have been too much enlarged in importance by some writers, and too greatly diminished by others. They must always supply one of the noblest fields of the study of the globe. Though nearly two hundred are more or less active at present, yet, excepting in South America, the space which they occupy is not very great, when compared to the surface of the world. When better criterions of minerals are established, it will form an interesting branch of Geology, to determine what countries owe their origin to volcanic fires which have acted in our atmosphere, and what tracts have been entirely raised from the deep by their power *.

The

---

* Buffon, and other writers, deny all stratification in volcanic districts. Kirwan, (Geol. Essays, 265.), who is of opinion that Vesuvius and Etna have not formed their own cones, and who acknowledges the conical shape of many granite and porphyry mountains, gives regular series of volcanic strata.

The necessity of a minute examination of every district, is no where more evident, than when we consider the quantity of transported rocks, which are found in many countries. This subject forms a part of all theories. So great has been the degradation, that comparatively but few tracts exhibit large continuous masses of granite at the present day*. The first debacle, we have traced, not to an accidental or an unknown cause, but to a necessary part of the formation of the world †. In many countries, and at a distance from their mountains, extended plains are often crowded with large blocks of stone; thus the sandy tracts of Pomerania and Prussia, on the south side of the Baltic, contain numerous masses of granite scattered rocks once occupying the spots of the present deposits, or that they have been conveyed from a distance, and been rolled, and worn during the operation. In several cases, the application of both these principles may be obvious. Nor is water the only transporting agent which we can employ. The appearance of floating islands of ice, entangled with soil and trees, has been observed, and forms a very probable origin for several of the phænomena. Thus, on the shores of the Baltic, the blocks of granite occur generally on the summits of the sandy hills; and none are found in the lower grounds. These summits would afford the first resting places for the masses of ice on which such blocks floated, as the waters retired*. It is more difficult to determine, in the present imperfect state of observations, which of these appearances we should refer to the last action of the waters, and which to an earlier change. When more countries are explored, and more phænomena accumulated, this may not be beyond our power.

---

* This was observed by Dr Hutton, (Illustrations, 305.) though he gave to granite perhaps too small an extent.

† Humboldt has inferred, that the direction and acclivity of mountain-ranges are phænomena posterior to the existence of the grand strata which compose the crust of the earth, and out of which he considers these inequalities on the surface as having been formed.

---

* See Sir James Hall's paper on the Revolution of the Earth's Surface, Edin. Trans. VII. 139. From his calculations, (p. 144.) we may infer the great elevation of the original mountains. After acknowledging a debacle with Saussure, he finally inclines to the opinion given in the text.

The great changes which have thus been traced, and to which we owe the present arrangement of the world, have obviously had their origin from causes which are not now to be observed in action. It is an interesting inquiry, to consider those changes of a slower kind, which depend on causes constantly acting at the present time.

While the Huttonian Theory is defective in proving the present existence of a great central heat, it is not less imperfect in its other principle, that of a general decay always going forward on the land, levelling the mountains with the plains, and conveying the materials of both to the ocean, during a prolonged series of ages.

It is true, that a mechanical destruction takes place to a certain extent. Heat, light, air, and water, are the agents. When the sun's rays shine on the cliff or side of a mountain, they expand the mass, and render it liable to separate. The daily variations of temperature must be supposed to act in the same mode on large as on small surfaces. Air, always holding aqueous vapour dissolved, is propelled against the solid masses of the mountains, by storms and tempests. Water is present in small quantity in the composition of many minerals, even in marble, which, when pounded and heated in close vessels, gives out steam. This water assists, more or less, in the destruction of all rocks; and when it is lodged in fissures, and converted by cold into ice, the destruction goes on with greater rapidity, because no bounds can be set to the expansive power of the liquid when in the act of freezing.

Granite decays in a mode which has been frequently described, and which we find exemplified on every mountain which contains it. The iron of the felspar is one of the greatest decomposers

decomposers of rocks. When it is acted on, and its degree of oxydation or of hydrature changed, the potash of the felspar is soon dissolved and carried off by the waters, a fine clay remaining behind around the particles of quartz. The porcelain-clay of our mountains, and the *kaolin* of China, are found, on analysis, to contain no alkali[*]. Over the surface of mountains of red granite, all the exposed and weather-worn blocks have a white aspect, from this decay of their felspar[†]. The sands consist of the large grains of quartz, with very little felspar. And hence, for the purposes of permanent architecture, white granites are far preferable to red ones, because, their felspar containing less iron, they change more slowly.

---

[*] *Kaolin* contains 71.15 silex, 15.86 alumen, 1.92 lime, and 6.73 water.—*Vauquelin.*

Porcelain-earth from St Yrieux in France, 61 silex, 19 alumen, 12 lime.—*Hassenfratz.*

[†] On principles formerly mentioned, a true *solution* of the materials of granite need not be inferred in its decomposition, the mechanical degradation being sufficient. In weathering, the constant application of water in rains, may have some effect in dissolving a stone containing potash.

The appearances of decomposing basalt are well known; they are accompanied by changes of colour in the stone, which have often been mistaken for the effects of heat; and it is only in spots where this substance has attained its greatest hardness and fineness of grain, or where perhaps less soda is contained in the rock, that the alterations from time appear to be least. Such is the case at the Mole of the Giant's Causeway, and at the cave of Fingal; while the debris at the bottom of the promontories of Bengore and Fairhead tends rapidly to decompose.

These are the causes of the wearing down of rocks; but these causes do not go far. Nature has set bounds to it. We even observe daily how destruction is met by a renovating cause, which prevents the degradation from being carried beyond a certain extent. Indeed, without some changes of the strata of the surface, no soils could have existed, and no life, either of animal or plant. The layers of rock wear down,—the granite falls into sand and clay,—and a resting place is thus provided for the seeds of lichens, which are constantly present. These, adhering to the loose or the solid surface of the rock, wear it still deeper in their successive generations, till a mould is gradually formed from their remains, mingled with the finely divided matter of the strata. Other vegetables soon begin to appear, and, as they grow, condense in their substance the carbon, oxygen and hydrogen of the rains and the atmosphere. The mould soon deepens; and as they die or decay, more perfect species succeed, till a soil is produced in which the trees of the forest can fix their roots, and the toils of the cultivator be rewarded by the abundance of the harvest *.

It

---

* This view of the subject has been given at greatest length by Willdenow, (Prin. of Botany, § 366.) He shews how to the minute mosses of the summits of mountains, we are indebted for the origin of our largest rivers.

The great hairiness of mountain plants, is an admirable provision; for thus their sharp points attract the dews more copiously.

It is thus that the decomposition of the rocks forms the soil, and even renews it, as the rivers and torrents bear down finely divided particles from the high to the low lands. In the same mode in which they were at first produced, the alluvial land is nourished, and the quantity of useful surface increased. Only a part of the substance of the mountains reaches the ocean, in rivers which flow through extended tracts of very flat country. Of what the ocean receives, a small part may be disseminated over its bottom, but by far the larger quantity is thrown back on the land*. Innumerable observations exhibit islands of sand and mud forming in the mouths of rivers†. The tendency of harbours is always to fill up, from the deposit of matter produced by the contending motions of the fresh water and the tides. Many lakes are gradually extinguished in a similar manner [*]. The waters of the rivers, before entering them, are often of brown or muddy colours from the strata over which they have passed; in traversing the expanse of the lakes, they lose their velocity and deposit their contents; and after leaving them, they offer to the eye very pure and limpid streams [†]. Many travellers have described this appearance in the Rhone, at its entrance and at its exit from the

---

* Many accounts of this have been collected. The deposit of land by the Nile, has removed Damietta some miles from the sea, since the expedition of St Louis.

† Major Rennell, in his memoir on the Ganges, has supplied many useful facts on this subject, which take place in the course of that river.—The banks at the mouth of the Thames require constant surveys from the Trinity-House, and are always shifting. Among the latest observers, see Mr Fleming, Wern. Trans. vol. ii. 1818, p. 341.

---

[*] See many examples of the basons or hollows formed by valleys, in Jameson's Geognosy, p. 22.—24.

[†] Thus the lakes in the line of the Caledonian Canal are gradually filling up, little of their alluvion passes to the sea.—It is well known, that the Po and the Rhine have been sustained for centuries by embankments, like the Thames, which, as high as Woolwich, is at ordinary tides *above* the level of the meadows, and is upheld by walls. In these cases, the bed of the river is raised by the deposit of its sediment, and in time, the tendency is to overflow the same tract which it had once assisted to form.

Lake of Geneva. In many lakes in Scotland, particularly in those which form a part of the course of the Spey, the process is completed, and some valleys in the course of that river are seen, which were lakes at periods within the reach of authentic records, and those in its course at present are gradually filling up*.

Dr Hutton, overlooking all these formations, saw Nature only operating in the work of destruction, and pointing with her finger to a period when no more land would remain to be destroyed. Of the time necessary he was indeed disposed to allow a sufficient length; and time was necessary; for the wearing of the rocks by the most tremendous waterfalls of Niagara or Tequendama † in a course of ages,
is

---

* In 1815, I examined the course of the Spey, from its source on the mountain Corryarick, near Fort Augustus, to Gordon Castle, with a particular view to this subject, to the nature and accumulation of the debris, and to the formation of the valley itself.

† Humboldt (Researches, vol. I. 72.) has described this magnificent scene in the Cordillera of the Andes, perhaps
the

is of no sensible quantity when compared to the size of the earth. Even here compensating causes are seen. The gulfs at the bottom of the cataracts receive the rocks which are displaced. The soil protects the strata below it from farther change, and the deeper it is, protects it the more powerfully. Every mountain has its sloping sides flanked with debris, which must all be removed before the central mass be itself attacked. In the precipices of the mountains or the sea-shores, the tendency of Nature is, to heap up piles of rocks at their base, and thus afford them a shelter. When the avalanche descends in an alpine tract, the ruins are too large to leave the valleys into which they are projected with such sublime terrors. And the highest peaks around rise, clothed in the eternal snows of that winter in which their

summits

---

the noblest cataract in the world. The Rio de Bogota falls at two bounds down 574 feet, and, in fact, from a cold to a warm region, as the vegetation around indicates.

summits always exist at a temperature which is nearly uniform throughout the year *.

In addition to these facts, Nature presents us with renovating powers of a more active kind, which the Huttonians also pass by unnoticed. Islands frequently emerge from the deep by the agency of fire, and many spots on the globe attest an origin of this kind. The small islands of St Paul and Amsterdam, in the southern Indian ocean, are eleven hundred miles distant from the nearest land; they offer every where volcanic rocks and hot springs; and they cannot have risen up at a period very remote, for a soil has not yet been formed, and only two species of plants have reached their dreary shores. In 1811, the new island of Sabrina

---

* Dr MacCulloch has drawn an important inference from the great equality which is seen in the state of preservation of the parallel roads of Glen Roy. The waste and destruction of hills, though certain, must be slow; for a more rapid destruction would have worn these roads unequally.—Geol. Trans. vol. iv. 387.

brina* arose in the Azores, and after some months was engulfed. Many similar phænomena have been traced of late years. The bed of the ocean is disturbed, its waters are heated, the fishes die and rise to the surface, bursts of flame spring up enveloped in clouds of steam, and these shroud the rocks which gradually or more suddenly emerge, and become new barriers to the waves.

The natural uses of Volcanoes are too obvious to be treated at length. We are too frequently accustomed to view them as agents of destruction only. They are so, indeed, locally, and often to a great extent. Their lavas overwhelm cities, their ashes cover the soil, and blast the harvest of the year. But the countries around them present the highest fertility, vegetation springs up with new force from soils preserved warm by their fires, and the sides of Vesuvius are clothed with vineyards. If the lava of this mountain does not often, from its nature, form a soil speedily*, the ashes which fall above it during the last days of an eruption, render it productive, and have made the country around Naples one of the most fertile spots on the globe, and still deserving the name of the Campania Felice. While volcanoes are thus the causes of its fertility, they have given rise to the country itself; for, from one extremity of Italy to the other, volcanic products crowd on the observer.

---

* So called from H. M. S. Sabrina, a party from which landed upon it, and brought away specimens of a white irregular pumice, inclosing small black crystals of hornblende. Philos. Trans. 1812, p. 152. See Sir G. Mackenzie's Travels in Iceland, for a description of a similar phænomenon near that island, p. 365.

Volcanoes thus present the most active scenes of the destroying and reproducing powers of Nature; but Nature, as fertile in her modes of working, as she is simple in her first principles, exhibits to us another mode of forming new lands, on a scale still more extended than by the agency of fire. The whole range of the Pacific is studded with islands which are formed of coral-rock, the work of mean worms, which inhabit the dwellings which they construct of limestone, by withdrawing lime from sea-water. Most islands in this ocean seem to have either a volcanic or a coral origin; almost all of them are surrounded by coral reefs, or ledges of the coral-rock more or less elevated. In the Straits of Sunda, and within one range of the eye, these islands are seen in all their stages of formation. First, low reefs and shoals appear, over which the waves break, and which navigators are anxious to mark in their charts. Gradually they rise above the water; the worms pursue their labours only on the surface; they attract rain and dews, wear down and form a soil, in which small plants at first take root; larger ones succeed, till at last an extensive island decorates the prospect, waving with palm and mangoe-trees, and the other productions of Nature in her tropical climates.

---

* The hardest lava receives a good soil by the Prickly Pear. " They bring a little earth to any crevice of lava, and plant a prickly-pear tree: it spreads, and splits the rocks in about seven years, and a thick plantation is soon formed."—General Cockburn's Travels in Sicily, &c. 1815, vol. I. p. 163.

Whatever destroying tendencies, then, exist on the earth, these renovating powers compensate for them. *They* never cease to act; nor do the heat, and air, and water, cease to destroy. No marks of a degradation acting throughout a prolonged sèries of ages are exposed to our observation, without being met by those of constant renewal. The one arises out of the other.—We infer, with certainty, that the present state of the World had a beginning, because that state arose from causes which do not now act. Just as its plants and animals must have received their first breath of life from superior power, because no new species are seen forming at the present day. That the CAUSE of all the appearances is one great and good Being, follows from the harmony, the magnitude, and the excellence displayed in mineral, vegetable, and animal existence. The time is not far distant, when the science of Natural Theology will receive a great accession from the proofs of design which Geology can unfold. But already we may safely conclude, that as the world did not commence, so it will not terminate from any causes at present in action*. In the great cycles of TIME, the infinite series of the renovating powers must be coeval with that of the destroying energies*. The Phœnix ascending with new splendor from the ashes of its parent bird, is the true image of that perpetual youth in which all things around us rejoice. Neither in the skies, nor on the earth, is the work of creation† ever at a stand. It elevates our ideas of the power of the ALMIGHTY, to infer, from the existence of worlds in all stages of formation‡, that His creating energies never sleep; that they constitute a perfection of His nature, and that

---

* See Playfair, Hutton. Theor. § 118, 119. where an opposite conclusion is drawn with regard to the *beginning* of the world, " there being (according to him) in the economy of the world, no mark either of a beginning or an " end."—On the other hand, I think it demonstrated, from every appearance in the mineral kingdom, and from the wisdom of contrivance and beneficence of design which it unfolds, that there has been a *beginning*; but I have not been able to trace any marks of imperfection or of termination in the present constitution of the world. This, as Mr Playfair justly remarks, is very different from concluding that the world will have no end.—An infinite succession of appearances implies the existence of a cause, as evidently as a finite succession. The Eternal may have connected all his beings in an infinite succession, and for this He, from his infinite nature, is the only true Cause.—See Dr Clarke's Correspondence with Leibnitz, 1717, p. 347, &c.

---

[*] It may be said that the transference of a very small quantity of matter over the bed of the ocean, in any limited period of years, will in *time* wear away the land. But it is almost unnecessary to remark, that an *inequality* between this effect and the formation of new land in the three modes enumerated above, must first be proved, before such a conclusion can be admitted to the smallest extent, in an infinite series of effects, of which a small part only is submitted to our observation.

[†] That is, the arrangement of matter in new forms.

[‡] See Sir W. Herschell's paper on the sidereal part of the Heavens, and its connection with the nebulous part. Philos. Trans. 1814, p. 248.

that all His operations are pursued in years and ages with an undeviating constancy, whether exerted in the heavens, the ocean, or the land.

The interesting direction which has been given, in our time, to the researches of Geology, has not been attained without a struggle. The extent of the actions, and the theatre on which they are performed, still recall to view the cosmogonies of ancient and modern times. Though the hypotheses of Burnett, Whiston, and Buffon, are now remembered only as instances of the presumption of the human intellect, yet, at the present day, opinions resting on no better foundation than the assumption of facts, have been given to the world. This is the more inexcusable, as Chemistry has now made rapid advances towards perfection, and some certain knowledge of the nature of Minerals has at last been attained.—The first theorists sought to penetrate into the nature of that *chaos*, from which the Almighty, by his omnipotent *fiat*, created the Universe. Others wished to account for the Deluge alone, by suspending the laws of cohesion and gravity, altering the position of the Earth in its orbit, or introducing a comet amid some storm in the planetary system. Around any single idea of this kind, the facts known in the mineral kingdom, were deposited; and these being far from numerous, and even uncertain, each theorist resorted to the sacred books for additional proofs of his opinions. The weaker that these were, the ardour for seizing them became greater, and the controversies between the contending parties warmer and more exasperated. The march of science overthrew them all, and entailed some disgrace on the subjects which they pretended to illustrate. Yet to this hour some are found, who, true to the unphilosophical mode of deduction employed by Burnett and Buffon, continue to write on Geology, as if this branch of knowledge had no other end but to afford conclusions respecting the age of the world, and the phænomena of the deluge. Revering the Christian religion, and finding in it the noblest objects of hope, the best exercise of the affections, and the highest ideas of the Almighty, I cannot but feel some shame and astonishment at these attempts. But I am unwilling to speak of that irritation consequent on controversy, which has contributed, more than any other cause, to render Geology an apparently contemptible pursuit. Some, wishing to affix their own unsupported signification to the short account of the arrangement of the world, recorded in the first chapter of Genesis, reckon every man an infidel who differs from them in the position of granite or basalt. Others condemn the Christian revelation in the mass, because they cannot find all the modern discoveries mentioned in the Scriptures. One of these superstitions may, perhaps, be exemplified by an extreme case, that of the present inhabitants of Patmos, who believe that the cross-like forms of the crystals of felspar in the rocks of their island were framed by the apostle John*; and the other, by the endeavours of many late writers to overturn the chronology of Moses, and the constant reference which it bears to the origin of the human race, by bringing forward the unphilosophical deductions of Mr Brydone, with regard to the long periods of time requisite to cover successive lavas with a productive soil *. These, and many other speculations of a similar kind, it is almost unnecessary to remark, are hostile to the spirit of true philosophy, which only reasons from what it observes. The progress of *facts* in the physical sciences can never be arrested by, nor come into competition with the subjects of faith. Though in some minds the Scripture accounts may strengthen, yet they can never of themselves support a body of physical truths, nor lend any but an adventitious assistance to the cause of science. The very latitude of interpretation which must be allowed by the most skilful divines to a few general descriptions, destroys all confidence when the objects are those of an exact science. In fine, to bring forward the Scriptures as the foundation of Geology is to degrade them, and not to assist it; to change them into weapons of controversial warfare; to stake their credit upon the most fallible of interpretations, that of a rising science not yet sufficiently furnished with facts; to contrast the unchangeable dictates of Revelation with what has hitherto been constantly subject to change.

---

* Dr Clarke's Travels, vol. iii.

---

* Brydone's Tour through Sicily and Malta, Letter vii. The defects of the reasoning inferred from his observations rest on two facts; (1.) That lavas possess textures of the most opposite kind, some decomposing rapidly, others never changing: (2.) That ashes almost always fall after the lava has flowed, and cover it immediately with a rich soil. Besides these, his idea supposes that each of the lavas was erupted at the distance of 2000 years from each other; of which no evidence can be brought.—The second circumstance is mentioned by Mr Brydone himself, in Letter vi.

On the other hand, no reason can be shewn why facts, established by long-continued observation and experiment, may not be applied to illustrate the Mosaic account of the creation *. This, however, is the province of the divine, not of the geologist. Let facts only be so applied; not hypotheses or cosmogonies. No true friend

---

* Mr Parkinson has well illustrated this, in his Organic Remains of a former World, vol. iii. p. 449—455.

friend of the Scriptures can require more; none of their enemies can wish to see them more degraded than they have been in very late writings of their defenders. To the Scriptures true knowledge has not yet been hostile; nor are they, when properly interpreted, enemies to it. It deserves to be remarked, that in countries where their pure light does not shine, a liberal interpretation of some passages has been allowed far more sparingly than in our own, which has so long enjoyed their benefits, and which is so deeply indebted to them for the high degree of civilization which it enjoys. It was in Italy that Galilæo was harassed by the Inquisition, because he had dared to prove the rotation of the Globe, and had enlarged the range of the eye and the mind, by turning the telescope to the Heavens. It was in the same country, and at a period nearer to our own age, that the learned commentators on the Principia of Newton, felt themselves obliged to acknowledge their unbelief in any physical tenets which the Church had condemned. With us the best divines have always held more liberal ideas on any passages connected with science. The age of our species is well marked by many events; and its progress in the arts and sciences, and its history, agree well with the relation of the inspired page. That this is the principal object of the first accounts in Genesis, and not any detailed account of the formation of the Globe, may be inferred from the shortness with which the creation is treated, and the length with which the dispersion of the leaders at Babel, over Europe, Asia, and Africa, is related. Many other circumstances lead us to the remark, that, in the account of the creation, Moses indicates the origin of our present world from materials which had previously existed, and been subject, as matter, to the power of the Supreme Mind. The formation of fish before land animals, is an interesting coincidence between modern discovery and the sacred account. Marks of a deluge are imprinted at every step; and that it did not alter permanently the face of the globe, may be inferred from the circumstance, that Moses describes the situation of some spots as being the same before and after that catastrophe. The absence of the remains of mankind in the strata, as far as observations have yet shewn, is favourable to this idea. But when the period of the six days has been supposed by some writers* to have been indefinitely longer than at present, in consequence of a slower rotation of the earth on its axis, and when we attempt to support this idea by the appearances of the mineral world, we start at once into the region of wild hypothesis.—From these considerations, I have left to others the application of the facts contained in this letter to the sacred accounts, I only say, that there may be drawn from the principles here unfolded, some considerations far more favourable to the Mosaic accounts, than any which are supplied by other theories. For no evidences of more than *one* arrangement of the world are exposed to our observation; and, since that arrangement did not arise from causes now acting, it must have had a beginning.—We find no traces of the materials of our present strata having originated from the decay of a former world. Only one formation of shells seems to have existed. Marks of a sudden formation, and of sudden revolutions, are visible in all the strata. Such principles, when well established, will aid the Scriptural account; but they would cease to do this, did they rest for their truth solely upon that book, which they are called in to illustrate.

---

* As in Bishop Horsley's Sermons, p. 446.

The termination of this prolonged discussion has now, my friend, been reached. In pursuing a track so extensive, it is essentially necessary that facts and observations should accompany the theory which attempts to generalize them; and that all our results should, if possible, be drawn from the nature of minerals themselves. The accurate discrimination of rocks should be connected with the study of their mechanical structure, and their chemical nature. Every research which tends to make us better acquainted with the relations of the strata of the earth to each other, is useful; and the greater part of the evidence which Geology has yet supplied, consists in the minute details of particular spots. Of how little utility the preceding remarks would have been, without the aids of Wernerian and Huttonian observers, the frequent references to their writings render evident.—Whatever may be the opinion of the public tribunal on the observations contained in these pages, I have, at any rate, received pleasure from the contemplation of the grand scenes of Nature,—from new ideas of her operations,—and from the views of that TRUTH, which the study of the Globe, if not at present, will ultimately impart to the mind.—I am, my dear Sir,

Your faithful Friend.

30th July 1818.

ADDITIONAL NOTES.

ADDITIONAL NOTES.

SYSTEM OF WERNER.

(Page 12.)

It is remarkable that the inferences hostile to the theory of WERNER, which can be drawn from his own descriptions of the strata, have very seldom been deduced. Of this theory the British public had indeed no accurate account, till PROFESSOR JAMESON published in 1808 his Treatise on Geognosy. Though this work is professedly elementary and abridged *, and may therefore be supposed to want in many cases the reasonings on which the conclusions must rest, yet it has been extremely useful, from the very accurate view which it gives of the *descriptions* of WERNER. These have been my guide in any researches which I have made, and in the greater number of cases I have found them of

uncommon

---

* Jameson's Geognosy, Advertisement, p. v.

uncommon accuracy, or rather, exact transcripts of the appearances seen in the rocks themselves, and in the mountains which are constituted of them. While this is willingly and justly acknowledged, it may be proper, at the same time, to declare, that by far the greater part of the *Theory*, founded upon these *descriptions* by WERNER, is either defective in explaining the appearances, or completely erroneous; and that, after all, his theory accounts for but very few of the phænomena which he was certainly the first to describe; as, for instance, for the whole of the questions connected with the strata, which I have stated above *.

It is not my intention, at present, to examine the theory of WERNER in detail; I shall only add a few inferences which follow from his descriptions, prefixing some extracts from the work of the excellent mineralogist already mentioned. These passages may assist the reader in recollecting the difference between the views given by WERNER, and those deduced in the preceding pages.

---

* Pages 63—65.

"Strata and beds appear to be particular
" and individual depositions from a state of so-
" lution or suspension in water [*]."

"The outgoings of the newer strata are
" generally lower than the outgoings of the
" older, from granite downwards to the allu-
" vial depositions, and this not in particular
" spots, but around the whole globe.

" The primitive part of the earth is entire-
" ly composed of chemical precipitations, and
" mechanical depositions do not appear until a
" later period, that is, in the Transition Class;
" and from this point they continue increasing,
" through all the succeeding classes of rocks, to
" the newest or the alluvial, which are almost
" entirely mechanical deposits [†]."

The Primary Rocks are also thus characterized:—" Excepting the small portion of mechanical deposit that accompanies the second porphyry formation, they are throughout pure chemical productions; and of these the

---

[*] Jameson's Geognosy, p. 56.

[†] Id. p. 79.

The *outgoings* of strata are the terminations of them which appear at the surface.

"older are more pure than the newer*." Since they are pure *throughout*, it is not easy to understand this gradation of purity.

The position of Quartz Rock between Topaz Rock and Flinty Slate, is a singular mistake already animadverted on. Quartz Rock is mentioned as indistinctly stratified †; whereas it occurs in very distinct strata.

"With grey wacke a new geognostic period commences, namely, that of the appearance of mechanical depositions ‡." As if there were none in gneiss, mica slate, &c.; or as if quartz rock had not been traced, by complete passages, to grains of rolled quartz.

"A white coloured granular foliated limestone, full of petrifactions, occurs in the Tyrol, and similar rocks have been observed in Switzerland, Bavaria, and Franconia §."

It is also acknowledged that whole formations of granular foliated limestone may occur in floetz rocks *. Now, if the organic remains are thus inclosed in a limestone so crystalline that it is only by geological position and inclosed minerals, that we can distinguish it from a primary one, it follows, that it should have been formed by a pure part of the solution; and if so, how did the petrifactions, which are also limestone, escape every trace of the action of this powerful solvent? The granular foliated and highly crystalline texture surely forbids, on the principles of Werner, the action of a mechanical deposit at all.

---

* Jameson's Geognosy, p. 101.

† Id. p. 143.

‡ Id. p. 149.

§ Id. p. 164.

The appearance here related is very common.

In the whole of the Wernerian Geognosy, we find no reason why some rocks should be stratified, and others unstratified. The universal water precipitates granite unstratified, and stratified rocks immediately above it, till those strata which all allow to be mechanical, gradually form. But in the *newest floetz-trap* formation, the order is reversed, and the most crystalline greenstone, is called an *overlying mass*, when it surmounts the strata of a basaltic hill, on the sides of which we find inclined strata of a mechanical and very new aspect*. This greenstone, too, is very often unstratified, though it is described as resting on strata, and though it often approaches in nature to unstratified syenites and granites.

---

* Jameson's Geognosy, p. 164.

We need not afterwards wonder, to find Werner "investigating the contents of the water of the globe at different periods†," and ascertaining with precision the age of the metals ‡.

The broken nature of the strata is ascribed to the rapid retiring of the water §, but as to where this water retired to, it is confessed that no satisfactory answer can be given ‖. It must have once stood very high over the whole earth, in order to afford a precipitation of our mountains from a chemical solution. Werner supposed that a part of the earlier formations was destroyed, ed, and matter for newer formations thus afforded[*]. This is a very probable hypothesis; but if the quantity of water which dissolved the primary rocks was not larger than even what we observe of their volume, it must have been immense.

---

* See the description of the Trap Hills in Saxony and Hesse, in Jameson's Geognosy, p. 201.

† Jameson's Geognosy, p. 86.

‡ Id. p. 256.

§ Id. p. 84.

‖ Id. p. 82.

Volcanoes, according to Werner, could not have their origin till those beds of trap and coal which supply them, and which are the newest of all rocks, were laid down. "They are, there-"fore, to be considered as new occurrences in "the history of nature, although they may ex-"tend far beyond historical record. The vol-"canic state appears to be foreign to the earth, "—a circumstance that points out its extreme "antiquity[†]."

It is remarkable that Werner has thus deprived his theory of the benefit of a single explanation of a mineral by heat, however indubitable may be the marks of heat in its structure.

Thus, for the cavities so profusely abundant in amygdaloid, there is no other explanation but that "they originate from air-bubbles *." In like manner, the effects of a compressing force, which give so great assistance to the theory of Hutton, are utterly opposed to that of Werner. In a precipitation or deposit of matter from water, the compression of the forming mass should prevent the formation of any drusy cavities lined with crystals, or of any orifices in basaltic rocks. There is no heat below to produce them, as in the Huttonian view. So in metallic veins, and whin and granite dykes, it is as incumbent on the Wernerian to explain the cause of the fissures, as to fill them with matter. In this respect, as well as in every appearance at the junctions of stratified and unstratified rocks, there are no satisfactory explanations in the doctrines of WERNER.

---

[*] Jameson's Geognosy, p. 97.

[†] Id. p. 96.

So striking are the two facts, that rocks are either stratified or unstratified, and that disturbances and the action of heat are seen at their junctions, that Hutton will always hold the highest rank as a Geologist, from his having been the first to observe and draw conclusions from these important phænomena.

In

---

* Jameson's Geognosy, p. 47.

In the universal dissolving liquid of Werner, acting on all the earths, inflammable and metallic substances of the globe, for few of which it at this day exhibits any powers of attraction, we have an hypothesis which cannot be reconciled to many of the descriptions of the same geognost. We may allow, that the deeper the water stood over the earth, it was the calmer *; but if the strata of floetz-trap were broken by the rapid retiring of the liquid, this introduces a cause as unequal as the eruptions of the Huttonian fire; and so capricious in its action, that we could scarcely expect from it the regularity which we see †. A calm rest is supposed to assist the regular crystallization of the first masses which were precipitated; but as the waters diminished, the disintegration began, "the crystalline shoots were destroyed," and the first mechanical productions appeared. Now this is inconsistent with the mechanical appearances in the most primary strata; for surely the arrangement of flat plates of mica in a direction parallel to the strata of gneiss, mica-slate, and clay-slate, is as decisive a mark of mechanical action, as when

---

* Jameson's Geognosy, p. 91.

† Id. p. 84.

when the same plates of mica lie in the same direction in beds of sandstone. It is also inconsistent with the phænomena of one junction of granite with the shistus. The liquid of Werner, too, retains to the last its chemical powers, and deposits beds of crystalline limestone, crowded with organic remains. It deposits these between secondary strata of the most mechanical kind *. So that we have here the inconsistency of the universal water separating chemical and highly crystalline strata, yet not acting on their organic remains, and immediately changing its powers, and letting fall a consolidated mud-like rock. Powers so capricious and so transitory were certainly never vested in any liquid but in the solvent of WERNER. This solvent, too, which let fall the unstratified granite first, and introduced newer and newer rocks above it, of partly chemical, partly mechanical texture, just reversed this order when it precipitated, by a subsequent rising, the formation of flœtz-trap. For there the most crystalline rocks, the greenstones and greystones, are the uppermost, and therefore the *last* members of what is denominated the *formation suite* †. In order to account

---

[*] As in Jameson's Geognosy, p. 164.

[†] Id. p. 84.

account for this discrepancy, the waters are supposed to have risen "tumultuously," deposited mechanical rocks, and afterwards become calm, yielding crystalline deposits[*]. So that we at last reach by a fair inference, the following result:—That the liquid of Werner, which dissolved the crust of the globe, acted as a chemical solvent or a mechanical agent, just as it was calm, or agitated by tumultuous movements. No other reason is assigned in the Geognosy of Werner: for no mention of precipitants is made.

Thus, by a philosophical induction, of which this country has seen no example for a century at least, Werner explains the structure of the globe. I confess that I never could find, in these inconsistencies with all our previous knowledge, any marks of "the comprehensive "mind," who has "fully accomplished" the theory of the world; nor of the "mineralogist "to whom we owe almost every thing that is "truly valuable in this important branch of "knowledge[†]." In fact, the accurate descriptions of WERNER have suffered, from the indiscriminate praise which has been heaped upon a theory that explains so little, and from those attempts to represent it as a system of perfect knowledge, which, in the present state of man, no science can be.

---

[*] Jameson's Geognosy, p. 84, 85.

[†] Id. p. 41.

CONSOLIDATION OF THE STRATA.

(Page 12.)

To find a cause for the consolidation of the strata, has been the object of the latest theories of the construction of the world. It is not difficult to shew, that the system of WERNER is entirely destitute of a power requisite to accomplish this great change.

The phænomena to be accounted for are the following:—the hardening of strata which all allow to be of mechanical deposit,—the consolidation of strata which, in the Wernerian Geognosy, are described as being partly of chemical, partly of mechanical formation,—the consolidation of strata, denominated by Werner crystalline or chemical,—that of unstratified rocks, granite, syenite, trap, limestone, and porphyry,

—lastly, the constant variations which appear in the degree of induration of all these rocks.

That water was present, is generally agreed, and is indeed proved by the facts enumerated in page 98. That it was water like that of our present oceans, may be inferred from the soda contained in minute portions in all rocks [*].

On the hypothesis of Werner, we have then water as a consolidating effect, assisted in the crystalline rocks by the strength of aggregation of crystallizing forces, and in all strata by the compressing force arising from depth and quantity of materials. Though the last circumstance is not mentioned by Werner, yet, as its action would obviously exist, it is unfair to deprive his system of the advantage which it appears to offer to his views.

The strength of aggregation of a congeries of crystals, is certainly something, though by no means so great as the induration of granites and traps appears to require. To indurate a *crystalline* rock, implies the absence of the solvent, or at least of its greater part, if it be aqueous. This Nature has done in these unstratified masses; but we have no analogical appearances to guide us, when we resort to our crystallizations from solutions on the small scale.

---

[*] See above, p. 223.—*Note.*

It is, in fact, unphilosophical to infer, that water had different or greater powers at the formation of the exterior of the globe, than those which it possesses at the present time. Passing by the obstacle arising from the *fragmented* nature of granite and trap, a circumstance alone decisive against a precipitation from a liquid, let us try if we can find any traces of the consolidating effects of water acting at the present day, and producing such a degree of induration as the phænomena of nature require.

We do not, then, find any marks of consolidating influence exerted in circumstances, and on substances, similar to those which appear constantly in the strata which all allow to be of mechanical deposit. In alluvial beds of gravel, however thick, we can refer to marks of formation by water,—to appearances of undulations,—to many circumstances which assimilate them exactly to strata of conglomerates and sandstones; but we observe no traces of consolidation in cases where water must have rested for a long time. So exact is the resemblance between alluvial beds of sand and strata of sandstone, that often no difference between them can be traced, excepting that the one is hardened and the other not.

In the sand of the sea-shore, at considerable depths, no change of this kind appears to be going on; nor is any consolidation visible in the gravel in the bottom of rivers. In bays with a sandy bottom, the lead always brings up sand. In other situations, mud adheres to the instruments of the mariner, though it is a substance far more easy of consolidation than gravel, and hardens speedily, with fissures, when exposed to the heat of the sun, which expels part of its water. The practice of anchorage is founded on these facts.

In hardening a bed of sandstone or conglomerate, a chemical solution of quartz is supposed by some to act between the interstices of the grains, and thus consolidate the whole into a rock. Hence WERNER speaks of sandstone combining a mechanical with a chemical origin.

If this solution of quartz were granted, it should evidently act upon the inclosed or rolled masses themselves, so as to degrade or dissolve part of their surface by its chemical powers. It would be difficult to shew that such a liquid ought not, too, to produce this effect in all cases. But, in very extended tracts of conglomerate,

glomerate, no marks of this are observed. I have found none in many cases; each nodule in the rock retains the worn surface which it originally received, when forming a part of the torrent from higher ground.

That the *whole* is not a chemical deposit, is surely evident from their perfect resemblance to the unconsolidated alluvial strata of the same substances, about the origin of which all are agreed. The theory of Werner rests upon their mechanical structure *.

Of the existence of a solution of quartz, we have, however, no proof.

Finally, if water consolidated sand and mud into hard strata, we have no cause for those constant varieties of induration which often take place within very small spaces †.

It must not, however, be omitted, that, though water itself does not appear to possess any hardening powers over substances, as gravel, for which it has no attraction, it yet offers proofs of consolidation, when acting on substances for which it exhibits affinity. Thus in

---

* See above, p. 53.—*Note*,—for Professor Jameson's opinion.

† These are accounted for in pp. 120, 121.

Parker's or Roman cement, and in stucco, a chemical combination arises between the water and the mineral substance, or part of it. The rapid hardening of volcanic ashes after a shower of rain, into a rock which requires the pick-axe to break it, is probably owing to a similar cause. When water holds suspended an oxide of iron, the deposit of that substance, probably as a hydrat, between rolled pieces of quartz, or other nodules, gives rise to an aggregation of which I have seen several examples, but none that were possessed of great strength. In like manner, other conglomerates are formed by stalactitical liquids. Clay forms a paste with water, and consolidates, by pressure, to a small extent; to a greater, if dried in the sun; but it can only, with propriety, be termed *hard*, when it has been subjected to the action of fire.

It is unnecessary to remark, that these appearances will not apply to the consolidation of sandstone strata. We have no resource but in the action of heat. It happens here, that *one well marked appearance of the action of fire* in the strata, a single junction of a whin-dyke, is incompatible with the whole theory of WERNER. The question is narrowed: shall we resort to a simple explanation, or to complicated hypotheses, which, after all, are completely unsatisfactory?

satisfactory? The effects of water in consolidating materials so diversified as those of the globe, cannot be inferred to exist; for water exhibits no powers of this extent and capacity of action. A sandstone of grains of quartz is infusible in our present furnaces; but its powder exhibits marks of agglutination at 90° of Wedgwood. And it has become probable, from these experiments with the blowpipe, in which rock-crystal has been fused, that in our best furnaces we approach a temperature which is not far removed from that which is required, not only to consolidate grains of silex, but to melt them on the large scale.

The action of a force, variable from its quantity or its distance, may thus be inferred to form a sufficient cause for the induration of the strata. The heat which melted the unstratified rocks below them, and hardened both in so striking a manner at their junctions, is a power adequate to all the effects which we observe. Water, if it possessed the power of hardening, would produce an uniformity of induration. But heat, from the mode in which it must be exerted, will give rise to a great variety of hardening. This variety may be traced over extended tracts of shistus. It forms a great mark of distinction between stratified and un-

stratified

passages of the partial inclinations of the strata into each other, (if I may be allowed the expression,) in the whole range of the mica-slate of the Highlands of Scotland, and in that of grey-wacke, which extends in Ireland from Belfast to the mountains of Kerry.—Thus, although elevations may have taken place in many of the strata, we have here a sure mark that these were never formed in a horizontal position, but in positions more or less approaching to those in which we behold them at the present day. Very regular strata of sandstone and other rocks undoubtedly often appear, and an original horizontal position may then be legitimately inferred, by Mr PLAYFAIR's reasoning, in which no defect can be found, but the absence of the fact which WERNER has described. It is in strata of gneiss, mica-slate, and grey-wacke, that the changes of the angle of inclination appear most abundantly.

In attempting to find a *cause* for this variety of partial inclinations in several shistose rocks, I have always seen it in one of those marks by which Nature has indicated the formation of the strata by the mechanical descent of their fragments through water, on planes of considerable inclination. On this theory, the various angles of inclination on which the fragments

that which can be extracted from the writings of any one of its defenders, but from several. Thus the *debacle* of Sir James Hall is introduced, though to the action of such a cause Dr Hutton and Professor Playfair are hostile[†]. Sir James Hall connects the doctrines of Hutton with the *debacles* of Pallas and Saussure. Hutton supposed an elevation of the contents from the sea so gentle, as to leave no trace of the event, and such as to have had no share in producing the present state of the Earth's surface, which was entirely modelled by causes whose action we can trace daily. Sir James Hall, on the other hand, speaks of successive and sudden starts, similar to volcanic eruptions, though far more powerful, and giving rise to immense waves, like those which are in some cases produced by earthquakes.—Even Mr Playfair admits, in order to explain beds of conglomerate, “ that the primary shistus, after at-
“ taining its erect position, had been raised up
“ to

---

[*] Illustrations, § 357.—Sir James Hall on the Revolutions of the Earth's Surface,—*Edin. Trans.* vol. VII.

" to the surface where this gravel was formed, " and from thence had been let down again to " the depths of the ocean, where the secondary " strata were deposited upon it *." Such is the complicated hypothesis to which, in order to preserve a consistency with his principles, and to represent all beds of gravel " as a production " peculiar to the beds of rivers, or the shores of " the ocean," this most eloquent advocate of the Huttonian system is obliged to have recourse.

The Huttonian Theory is in fact not only untenable, from the objections given in the text, but, as Dr Hutton left it, it is contradicted by the size of every valley in which the marks of larger rivers than now roll in them are seen on the form of their sides, in their alluvial beds of gravel and clay, and in the channels worn in the large masses of rock placed beyond the reach of the present streams.

Another great defect in the Huttonian System is, that besides neglecting those numerous marks of *rapidity of formation* which are visible in many strata, it represents all strata as being originally formed in that horizontal position

---

* Illustrations, § 44.

tion which a deposit of fine matter spread over the bottom of the ocean, could alone assume. Mr Playfair indeed allows, that the form of the bottom might influence, in a certain degree, the stratification of the substances deposited on it *. He is inclined to think, however, that this cause acted to no great extent, and that there exists a great parallelism of thin beds and strata in sandstone and in primary shistus, and hence he draws the inference, that because some vertical and highly inclined strata have been formed horizontally, there can be no reason for not extending the same conclusion to all †.

Most theories of the Earth have either formed the strata originally horizontal, and have elevated them, or they have always allowed for causes which had produced disturbances in their position.

When we compare, here, the Huttonian hypothesis with the descriptions of strata given by Werner, we see the difference which exists between a theory formed without a sufficient observation of mountains, and a description of the appearances of Nature.

"It

---

* Illustrations, § 38.

† Id. § 42.

"It is of the greatest importance to di-
"stinguish the *general* direction and inclina-
"tion of strata from the *partial.* To effect
"this, we must take the results of a number of
"particular observations, and compare them
"together; and those similar angles which are
"the most numerous, are to be considered as
"expressive of the general inclination and di-
"rection *."—"Beds which are perpendicular
"at the surface of the earth become gradually
"more horizontal as they descend †."

Every person who has traversed a mountain tract with the compass in his hand, has found the truth of this description of WERNER. If in an extended tract of country, as of the rocks called *transition grey-wacke,* we should find an inclination constantly varying on the large scale, and if we found this inclination equally varying in the small scale, as within the distance of a few yards, this would be a proof that the strata had been originally deposited on inclined planes. For, on the supposition of a formation so regular as a horizontal one supposes, the act of elevation should have no power to produce such minute variations in the inclination. In grey-wacke and mica-slate strata we often find these variations of inclination within the shortest spaces. Mr **Playfair**, on the other hand, has reasoned from there being a perfect equality in the component laminæ of these rocks, in all cases *.

---

* Jameson's Geognosy, p. 52.

† Id. p. 224.

When observers are at issue with regard to facts, as has too often happened in Geology †, and often in very remarkable examples, the progress of truth is never impeded long. It is the peculiar duty of a writer on this science to attend minutely to the accounts which he lays before his readers, and if he can quote the observations of others on spots which he has himself visited, an additional proof of their certainty is presented. In the present case, all my observations over extended tracts of mica-slate and grey-wacke country, have confirmed the description of Werner. I have observed, in innumerable cases, the successive passages of the partial inclinations of the strata into each other, (if I may be allowed the expression,) in the whole range of the mica-slate of the Highlands of Scotland, and in that of grey-wacke, which extends in Ireland from Belfast to the mountains of Kerry.—Thus, although elevations may have taken place in many of the strata, we have here a sure mark that these were never formed in a horizontal position, but in positions more or less approaching to those in which we behold them at the present day. Very regular strata of sandstone and other rocks undoubtedly often appear, and an original horizontal position may then be legitimately inferred, by Mr PLAYFAIR's reasoning, in which no defect can be found, but the absence of the fact which WERNER has described. It is in strata of gneiss, mica-slate, and grey-wacke, that the changes of the angle of inclination appear most abundantly.

---

* Illustrations, § 39.

† One of the most remarkable instances of this is in Jameson's Geognosy, p. 237. where we read: "It is an "incontrovertible fact, that no veins of the substance of a "subjacent rock ever shoot into a superincumbent one."

In attempting to find a *cause* for this variety of partial inclinations in several shistose rocks, I have always seen it in one of those marks by which Nature has indicated the formation of the strata by the mechanical descent of their fragments through water, on planes of considerable inclination. On this theory, the various angles of inclination on which the fragments rested, would be modified by the inclination of the base or support, the direction of motions or currents, the size of the fragments, and their shape. While partial inclinations thus arose, a general inclination over an extended tract would still remain. And the rocks on which this appearance occurred, would be those of which the fragments are largest, as gneiss, mica-slate, and grey-wacke of large grained varieties; in strata of finer particles, as clay-slate or sandstone, the appearance would not exist at all, or far more sparingly. All my observations have confirmed these ideas.

CENTRAL HEAT.

(Page 23.)

IT is almost unnecessary to treat of this subject at the present day.—No satisfactory evidence of the present existence of a central fire was ever brought forward, excepting that which arises from volcanoes. However active and abundant these are, they bear but a very small proportion to the extent of the surface of the globe. Their size, and the heights to which they elevate their lavas and ashes, are by no means such as would be presented, were they to approach the centre of the earth, or to descend through its mass to a depth of two or three thousand miles.

Yet the Huttonian Theory requires the present existence of a central heat to produce those changes on the globe which gradually lead to new formations. Mr Playfair has defended the mode of action of such a central reservoir of fire, in an investigation which Dr Murray has certainly shewn to rest on data which cannot be reconciled with our knowledge of the laws of that power. And, lately, the subject has received a still greater certainty from the profound investigations of Professor Leslie, with regard to the quantity of heat sensible below the surface, the temperature of the ocean, the cold impulses from a clear sky, and the modes in which the solar rays, the only fountain of heat to our planet, find their distribution over its surface, and their relations to air and water, in an admirable economy, which he has been the first to discover and describe.

EXPERIMENTS SHEWING THAT THE WERNERIAN ORDER OF SOME OF THE PRIMARY STRATA IS PRESERVED IN A MECHANICAL DEPOSIT.

(Page 82.)

IT was after ending a long tour in Braemar in the autumn of 1818, that, having become at last convinced of the mechanical deposit of the primary strata, from their resemblance to the secondary in so numerous relations, and from the mechanical aspects visible in them, I made some of the experiments described in the text. The first trials were, however, so imperfect, that the subject was neglected for nearly two years, till I found a small-grained granitic sand which answered better than the materials used in the first attempts. In the mean time, I inferred the necessity of a mechanical origin, from the fact that specific gravity, size, and form of fragment, must have acted; the plates of mica alone, viewed in their position in the strata, shewed it; and I found the best description of these, and of the constant transitions, in the Geognosy of WERNER.—These experiments, with small-grained fragments of felspar, quartz, mica, and clay-slate, will yield good results; the materials of granite never unite again as granite at the bottom of the box; and not unfrequently the results are more regular than the strata of these rocks themselves generally present. For, in nature, the great heights from which the fragments are supposed to fall, and the variety which must have prevailed in the heights from which they descended, must tend to introduce more irregular transitions than experiments on a small scale can be supposed to afford.

MECHANICAL STRUCTURE OF THE STRATA.

(Page 86.)

To the examples given in the text of the mechanical structure of quartz and mica-slate rocks, I may add the appearances seen in the quartz mountains of Ireland. On the summits of the two Sugar-loaf mountains of the county of Wicklow, and on the promontory of Brayhead which is connected with them, I found many examples of rounded and worn pebbles of quartz in the rock. The strata of these hills observe that direction from NE. to SW. which is seen so uniformly throughout the strata of Ireland. At the peninsula of Howth, the same direction is visible in the quartz rock. At the quarries above the new harbour of that place, there are, in a short space, all the varieties of passage from compact quartz-rock to clay, the latter lying above the former, offering every variety of induration, approaching in its colours to band and porcelain-jasper, and containing more and more quartz till it passes, with a splintery fracture, into quartz-rock.

From my observations on the quartz-rock of the county of Wicklow, and its connection with the mica-slate strata, visible at Powerscourt waterfall, I am inclined to think the former rock subordinate to the latter in that tract.

No capital in Europe is situated so favourably as Dublin for observations on primary and secondary strata. The unstratified granite formation of Wicklow is on so small a scale, that the principal phænomena of it and the rocks above it can be observed within a small compass of ground; in this respect constituting a great contrast to the very extended scale on which the greater part of the Island has been arranged, in large formations of transition grey-wacke, and more secondary rocks, which preserve for two hundred miles a great uniformity of direction in their strata. The conclusions which may be drawn from so continuous a formation of grey-wacke are of considerable interest in the study of rocks on the large scale; and I hope to be able soon to publish the results of the examination which I have made.

The veins of granite shooting through the incumbent mica-slate in Killiney bay near Dublin, the hardening of the shistus, its contortions, and the separation of colours which appear in it at the junctions, are all of the most interesting kind.

The Wernerian doctrine on the chemical formation of gneiss and mica-slate, is defended by PROFESSOR JAMESON [*], from the appearance of the crystalline fragments of these rocks. The view of their formation given in the text, necessarily supposes more of this appearance to be preserved in them than in those rocks which have been longer subjected to the disintegrating process, and have been ultimately deposited at a greater distance from the action of heated granite. This subject is deserving of a detailed examination.

---

[*] Geognosy, p. 345.

SAUSSURE and VON BUCH have found rocks of decidedly mechanical structure interstratified with clay-slate, gneiss, mica-slate, and even with stratified granite.

One Wernerian answer to this difficulty is, to refer all Primary rocks in such positions to the class of Transition rocks. This offers a far more complex idea to the mind, than to consider them all as parts of one great formation, in which the mechanical appearances would continue to increase from two causes;—a disintegration carried to a greater extent, the farther its materials were removed from their source, and an action of heat more powerful in proportion to its vicinity to the first deposits of primary strata.

DR MACCULLOCH, after describing several mechanical appearances in mica-slate and quartz-rock, adds;—" A mechanical arrangement in the shistose rocks appears a circumstance attending on many of these, as perfectly demonstrated as any thing, of which we have not actually witnessed the creation, can be demonstrated to our senses *."

ON

---

* Geolog. Trans. vol. iv. p. 230.

ON THE FORMATION OF STALACTITES.

(Page 105.)

Since so large a part of the reasoning employed here, depends upon the mode of formation of Stalactites and Stalagmites, I shall relate what I have observed respecting them in stalactitical caves.

In the caves which are abundant in limestone tracts of country, and where the rock is pure or nearly so, the stalactitical appearances are seen in the distinctest manner. From the wide or narrow fissures in the stratified rock above, the percolating water descends slowly, and falls in successive drops on the floor below, with a slight noise, which is the only sound heard in these caverns.

The shape of the drop of water first deserves attention. Like that which is descending from any plane surface, or from a tubular orifice, it is narrowest at its lower convexity, and as it gradually approaches a contact with its support, it widens, till reaching it, it spreads out in a wider expansion over the surface to which it adheres. As this surface receives from the fissure the small ramifying streamlets, the drop increases in size, till a spherical globule, able by its gravity to overcome the cohesive attraction of the water to its support, separates, and falling down, dashes on the floor.

Such is the case with drops of water in all similar situations of gradual increase and descent. Let us suppose that the minute streamlets, which form a drop in a limestone cave, either hold dissolved or suspended small particles of carbonate of lime, and that these are precipitating or depositing. Then it is always observed, that the first deposit of matter takes place around the origin of the drop, where it spreads out over the limestone surface from which it depends. A circular row of particles is thus formed, and united to the solid rock. Other rows or layers succeed, applied to the former, and following in their flexure the shape of the drop.

This constitutes the origin of the stalactitical column, which at first presents a thin circular crust, of the same concave appearance with the upper part of the drop of water. Its breadth is nearly a quarter of an inch at its lower end, but it tapers to double that diameter at least at its root above. Its length will be less than that of the drop at first; but this speedily increases, and the drop finding in its interior the channel by which it descends, it offers a cylindrical tube nearly perfect, and about three inches in length, still preserving its original diameter, with the exception of the part where it is attached to the rock, and which I shall denominate its *root*.

The substance of these tubes is thin, brittle, and translucent or semitransparent. Traces of a minute crystalline structure are seen on their exterior, which preserves a considerable smoothness. In the interior, the passage of the drop continues to deposit matter, and minute pyramids of calcareous spar begin to appear. These increase most rapidly in the lower end; for there the deposit from position, takes place most abundantly. The extremity of the tube ends always in small pyramids, whence the drop of liquid, which is part of the fluid which fills the tube from capillary attraction, depends. The diameter of the column is bounded, as I have described, by the uniform size of the drop in a calm and secluded atmosphere, not very liable to be influenced to a great extent by those variations of heat and cold which would diminish or enlarge it. Its length is more variable, seldom less than two, or more than four inches, and appears to be determined chiefly by the force of the capillary attraction between it and the water; for the latter, having to percolate amid numerous minute pyramids of spar, will obviously deposit its contents higher or lower in the tube, according to any accidental circumstance which may give rise to the formation of the first pyramids which project from the interior of the translucent crust; and thus a crowding of the crystals unequally in the tube will diminish the orifice, and extend the influence of the capillary cohesion. Still these tubes preserve a pretty uniform length, particularly in the marble caves, about six miles from Kilkenny in Ireland, where many hundreds of them hang from the roof, averaging three inches in length.

Thus the drop continues to percolate through a passage which is always narrowing as the accumulation of matter proceeds, till the tube is completely filled at the bottom by the union of the pyramids.—The rest of the process may be more briefly described. The filling taking place from the bottom, the calcareous matter gradually ascends, till the fluid no longer finds a passage through the crystals. Nature then pursues the accumulation of the stalactite in another mode. The little pillar, now become solid, increases on the exterior by the descent of water over its surface, a descent which has been constantly going on; and a drop from this also rests on the tip of the column. The increase continues, till, by the union of many pillars in a course of years, columnar masses arise, like those of Antiparos or Sky.

The *stalagmite* below is formed by the matter deposited by the drops which fall on the floor. Here the natural tendency of depositing matter is to accumulate in blunt conical shapes. These are at first of thin foliated structure; their layers thicken by the constancy of the deposit; and gradually increasing, they often rise so as to unite with the pillars which descend from above.

Where the limestone is not pure, but mixed with siliceous or argillaceous matter, I have constantly observed, that a concentric structure prevails in the columns, either on the large or the small scale. This forms another proof of the principle proposed in p. 171. It shews us that the rhomboidal, pyramidal, and prismatic forms of pure carbonate of lime, are interrupted by a complexity or impurity of substance, and that then concentric and radiated shapes of imperfect crystallization come on. Such appearances may be traced in all situations where the deposit is not pure; as in caves in trap rocks containing calcareous spar, or beneath the arches of bridges, from the matter percolated from the mortar which is used in their construction.

In the large and pure stalactite, the concentric form only remains near or at the surface of the pillar; the interior offers a complete crystallization; and the fact to be accounted for is, how a large and perfect rhomboid of spar arises from the deposit of small particles of matter. No formation of the whole at one time, no simultaneous process, is necessary to explain the appearances; for Nature offers to our view the series of the formation going on in all its parts.

Some of the older Geologists filled the caves with liquid, and then precipitated and crystallized. Every thing contradicts this supposition. If we did not see the small stalactites forming, or the larger ones increasing before our eyes, their shapes alone would shew us that they have had their origin in the air.

Two explanations only remain. The one, that the water, containing carbonic acid gas, is thus enabled to dissolve carbonate of lime, which it lets fall as the gas evaporates. The other, that water conveys the carbonate of lime in minute particles to their destination by a mechanical transit.

I do not deny the presence of carbonic acid gas in these situations; and from its existence in the atmosphere, and its relation to water, its presence in larger or smaller quantities may always be inferred. If we allow it, the deposition of particle after particle is still as mechanical as on the other hypothesis. And we have still to account for those stalactites which contain sand and clay, and for siliceous stalactites.

Though Dr MacCulloch * is of opinion that a solution of silex in water is a process still going on, yet it is certain that pure water rests on the surface of quartz, rock-crystal, or sandstone-rocks, without exhibiting any vestige of a siliceous solution. The only case in which silex is dissolved by itself, (excepting when brought into the state of air by fluoric acid), is in the well-known experiment of precipitating it from a *liquor silicum*. Here the minute state of division is commonly assigned as the cause of the solution. But is it not more consistent with all our chemical knowledge, to ascribe the appearances in this experiment, either to a partial suspension of finely divided matter, or to the presence of alkali imperfectly disengaged from the earth? A true chemical solution is that where water attracts and is attracted by the substance which it dissolves. No attraction is sensible between silex and water in all ordinary circumstances. On the hypothesis of a mechanical passage of water, these difficulties disappear; and the whole is well related to the other facts mentioned in the text.

---

* Geological Transactions, vol. IV. p. 266.

On this subject I may add, that I have not drawn any conclusion from that transference of solid, liquid, and gaseous matter which is seen so distinctly in the circuits of the pile of VOLTA. Here ammonia in the state of gas traverses the substance of quicksilver; sulphuric acid passes through a solution of potash without uniting with it; while in these and other appearances the moist threads of flax or asbestus render this passage visible to a certain extent. Though these phænomena are among the most interesting in physics, and offer to us the most unequivocal proofs of the mechanical transit of matter, yet as the subject is complicated with other considerations, I have not stated it in the text. In the explanation of the contents and arrangement of metallic veins, and in the explanation of crystallization itself, the action of electrical currents may, when observations are more multiplied, supply us with a true theory of these phænomena, which is still so much wanted.

I shall only add the accidental circumstance which first drew my attention, nearly ten years ago, to this subject. A saturated solution of nitre had been prepared in summer, and afterwards laid aside, to be used in an experiment of crystallization. In the following winter I found at the bottom of the phial one very large and regular prism with perfect dihedral summits. I was led immediately to the inference, that the deposit of matter from a chemical solution like this, is as mechanical an effect as their structure itself exhibits. This was strengthened on afterwards finding crystals of nitre and other salts left on a plane surface, at some distance from each other, after slow evaporation of the solvent, as mentioned in the text.

ON THE HUTTONIAN EXPLANATION OF SOME MINERALS AND MINERAL VEINS.

It is remarkable, that some of the minerals whence Dr Hutton drew his most powerful arguments,

guments, are exactly those which no ingenuity can reconcile to the action of heat. The Neptunians of this country, stated this at an early period of the controversy; but, proceeding farther to explain the phænomena of Graphic Granite and Septaria, on the principles of chemical solution, their ideas, being unsatisfactory to all acquainted with the state of chemical knowledge, the explanations of Hutton came to be regarded as at least as good as those of their opponents.

It has been, indeed, for a long time the opprobrium of the geological reasonings of both parties, that, leaving a strict inductive course from the known laws of heat and solution in liquids, they have ascribed to both these agents, powers of which we find no proofs in Nature. If it be said, that water and fire had other properties at the formation of these minerals, than they have at present, no evidence of this can be brought. Since such an hypothesis will explain the appearances in conformity to the views of either party, both theories meet here on equal ground, and both are equally unsatisfactory.

Thus the Graphic or Portsoy Granite has been already shewn to be inexplicable on either hypothesis*; as well as the numerous instances where crystals of one mineral shoot through the substance of another. I have a specimen where the same crystals of rutilite shoot through rock crystal and sulphuret of lead; the first a more infusible, the second a more fusible mineral than the penetrating crystal.

---

* See above, p. 109.

In arguing for the petrifaction of wood by a melted liquid penetrating it, PROFESSOR PLAYFAIR has been more successful *; and some specimens may have been formed in this mode †. But not one fact has ever appeared to reconcile to the appearances, his account of the presence of nodules of flint in chalk strata, by injection when fused from below. The regular arrangement of the flints in the strata, which he does not mention, ought alone to have prevented this singular explanation from being brought forward ‡; since their presence there is as evidently owing to the action of water, as any circumstance yet ascertained in Geological Science.

The well known *Septaria* or spheroidal ironstones, on which DR HUTTON § laid so much stress, exhibit marks of both aqueous and igneous action. The action of water may be inferred from the evident mechanical nature of their substance, which is an iron-clay. The influence of heat appears in their possessing every variety of induration. Balls of iron-clay, formed by rolling, and fissured by the sun's rays, appear to have been afterwards, in many cases, penetrated by stalactitical deposits, and subsequently heated, often to a considerable degree. In the same specimen, it has appeared to me, that we have the accumulation of matter by water, the marks of rounding, the formation of stalactites, and the evidence of heat.

---

* Illustrations, § 19.

† See above, p. 217.—*Note.*

‡ Playfair's Illustrations, § 20.

§ Id. § 26.

The subject of MINERAL VEINS has been long the conflicting ground of the disciples of HUTTON and WERNER. The descriptions of the latter geologist guide us to accurate ideas of their structure; but several facts still remain to be ascertained with precision, before a true theory can be advanced. The variety of their contents, and their regular disposition along the sides of the vein, present obstacles to a full explanation. In the account of the fissures by Werner, we find no cause which can be denominated satisfactory :—" These fissures may " have been formed in different ways, as by " the unequal accumulation of rocky matter at

" the time of deposition; by the loss of support, owing to the diminution of the water; " *by the desiccation of strata, caused by the* " *consolidation of crystalline depositions;* sometimes by earthquakes, and the softening of " strata during long-continued rains*." The last reason is the most remarkable of the whole. The action of heat is a cause much simpler, and indeed alone competent to explain the fissures. It is probable, however, as far as appearances have yet shewn, that some veins have been filled from above. It may be shewn, too, that, admitting the formation of the rents by heat, they might, in some cases, be wider below than above; in others narrower, from the effects of that power. *Lying masses*, and those large metalliferous cavities, denominated *Putzenwerks*, also offer peculiar appearances, intimately connected with regular veins.

Whatever explanation of metallic veins be finally adopted, it is evident that the theory of WERNER is entirely inconsistent with the present state of our knowledge. Let us allow the presence of a liquid which dissolves all their materials, and the action of precipitants to separate them;—still the veins could not offer their present appearances, because the depositions of matter should be entirely horizontal, and not parallel to the sides of the vein; because in the veins, there is not room for the presence of the materials and the solvent at the same time; and, finally, because if it be attempted to obviate the last mentioned objection, by supposing a circulation of the liquid till the whole vein was filled, this is opposed by two considerations;—the presence of such large quantities of metallic liquids as would be then required, and the marks of rapidity of formation in many strata, which would obviously prevent that circulation of the liquid on hydrostatical principles, in such periods of time as would appear probable. It has always, too, been remarked, that the shapes of many of the strings and branches of veins, prevent such a circulation of fluid from having ever taken place in them.

---

* Jameson's Geognosy, p. 240.

PITCHSTONE PORPHYRY.

(Page 143.)

Since this sheet was printed, I have found that DR OGILBY of Dublin was the first who traced, several years ago, the transitions of the Porphyry of Sandy-brae, in the county of Antrim. He discovered that it passes, on the one hand, into porphyritic clay-stone, and clay of little induration; and, on the other, into compact felspar, and rarely into a mineral approaching in its characters to red jasper *. These observations of this excellent geologist, are extremely valuable, from the relations which they present between this porphyry and the red Causeway clay.

DISINTEGRATION

---

* See a Note of Dr Ogilby's Discoveries in Tilloch's Philos. Mag. 1812, vol. XXXIX. p. 398.

DISINTEGRATION OF THE STRATA.

(Page 260.)

MR STEVENSON, in the second volume of the Wernerian Transactions, has lately collected numerous appearances of the wearing away of the coasts of the British Islands, and ascribes the changes to the rise of the German ocean, in consequence of its base being elevated by the spoils poured into it in a course of ages.

These observations are extremely useful in Geology; and they should be connected with the numerous formations of new land which are constantly going forward on the same coast, and many of which have attained to a considerable extent within the period of the last century. Of those on the Scottish and English coasts, I have collected several instances.

Cuvier has related several appearances of this kind on the shores of the Hadriatic; and many others have been enumerated by different writers.

But the want of extended observations on the level of the sea, is still felt as much as ever by Geologists; and Mr Playfair, after he has ascribed the sinking level of the ocean on our coasts to the slow elevation of the land, acknowledges the imperfection of the data which have been hitherto brought forward *.

Where our observations stop, our reasonings must cease. It can only be said, that, as this question stands at present, many proofs of the rise of the sea, in some spots, and of its retreat in others, have been observed. But, in a series of changes, of which we have hitherto examined but a very minute part, we cannot expect, as yet, the confirmation which a true theory requires. At any rate, we have no data for believing in the hypothesis of Hutton, that the land is slowly rising by the central heat, and thus exhibiting to us a diminished level in the ocean. The fact, that in this theory the *bed of the sea* is constantly separated from the continents and islands to which it is contiguous, and of which it forms a part; and the idea of the heat only acting to elevate the land, without raising at the same time the bed of the ocean

---

* Illustrations, § 401.

ocean itself; are assumptions to which there is certainly attached nothing of that spirit of philosophical induction which can alone guide us to the truth.

It may still be said, in opposition to the views taken in the text, that, after allowing all the causes which tend to preserve the mountains, if one ounce of matter finds its way to the bottom of the ocean in one year, or in a thousand, the destruction of the present order of things may finally be attained, as surely as by the most rapid decay.

" These operations," (says PROFESSOR PLAYFAIR), " inconsiderable if taken separately, become great, by conspiring all to the same end, never counteracting one another, but proceeding, through a period of indefinite extent, continually in the same direction. Thus every thing descends, nothing returns upward; the hard and solid bodies every where dissolve, and the loose and soft no where consolidate. The powers which tend to preserve, and those which tend to change the condition of the earth's surface, are never *in equilibrio;* the latter are, in all cases, the most powerful; and, in respect of the former, are like *living*, in comparison of *dead* forces. Hence the law of decay is one which suffers

" no exception. The elements of all bodies
" were once loose and unconnected; and to the
" same state nature has appointed that they
" should all return*."

The imperfection of this reasoning consists in the affirmation, that no formation of consolidated land is daily going forward; and in its neglecting the constant relation which Nature offers to our view, between this formation, and the decay and waste of all mineral substances. We cannot prove that the new land, raising by the action of the sea, by coral-worms, or by volcanic fires, is exactly equal to the waste of the present continents, because we are not yet provided with a sufficient number of facts and observations to be able to state this equality. It is an immense series of effects, of which, in any assignable period of time, we can observe only a few. But, for the same reason, no Huttonians can prove that they are *unequal*, and that the decay preponderates over the renovation. This it rests with them to do. If it cannot be shewn to be the fact, the principle of Dr Hutton, that the land is gradually wearing away, becomes an assertion, of the truth of which we have

---

[*] Playfair's Illustrations, § 114.

have indeed innumerable proofs, if we regard it *by itself;* but of which we have no evidence whatever, if we consider it as a part of the system of the world, which is met by constant renovating powers. The land indeed decays; but the moment the decay commences, we have seen that preserving forces begin to act on the sea-shore, on the banks of rivers, and on the precipices of mountains [*]. In prolonged periods of time, the ultimate decay which goes slowly forward, is met by the consolidation of new land which rises from the ocean. In this beautiful harmony, extending around the globe, and acting in every mountain and plain, every river, and every sea, Man is enabled to view but a part; but from that part he can infer with certainty, that no inequality, no want of an exact equilibrium between the destroying and renewing forces employed by NATURE, has yet been found [†].

---

[*] See *above*, p. 253.

[†] It is not here concluded, that no marks of inequality between the decay and renewal may not be found in future times, and after more extended observations than we at present possess, are collected; but only, that no traces of inequality of the destroying and renewing forces have *yet* been shewn to exist by Dr Hutton and Professor Playfair.

CONNECTION OF GEOLOGY WITH THE SCRIPTURES.

(Page 265.)

In this passage, I have done little more than expand the ideas of LORD BACON:—

"Pessima enim res est errorum apotheosis, et pro peste intellectus habenda est, si vanis *accedat* veneratio. Huic autem vanitati nonnulli ex modernis summâ levitate ita indulserunt, ut, in primo capitulo Geneseos, et in libro Job, et aliis Scripturis Sacris, philosophiam naturalem fundari conati sint; inter VIVA quærentes MORTUA. Tanto magis hæc vanitas inhibenda venit et coercenda, quia, ex divinorum et humanorum malesana admixtione, non solum educitur philosophia phantastica, sed etiam religio hæretica. Itaque, salutare admodum est, si mente sobriâ, fidei tantum dentur quæ fidei sunt."

Nov. Org. Lib. 1. *Aph.* 65.

This is a passage which cannot be too often remembered, and which, like many others in the same immortal work, is pregnant with the spirit of true wisdom. It seems, as PROFESSOR PLAYFAIR justly remarks, to have been prophetically addressed to De Luc, Kirwan, and the other cosmogonists of the present day, who have done all in their power to degrade the Sacred Writings by the arguments which they have brought forward in their defence.

It is somewhat painful to revert to such opinions, even when published under the sanction of great names, or embodied in the Transactions of Learned Academies. So mischievous, and so destructive of private and public peace do some of these speculations become, that whatever attention we owe to the facts and descriptions of these writers, we owe no regard to their arguments on this subject, with which they have intermingled their discussions on minerals and strata. Posterity will scarcely believe, that a question exactly similar to many agitated in the tenth century, and in the darkest schools, was discussed in many pages by De Luc and Kirwan. De Luc ascribing the strata to the Deluge, maintained that Noah's olive branch grew on an island which floated and survived the wreck.

Mr Kirwan [*] combats this idea; and De Luc, in his Travels, returns at great length to the charge. Mr Kirwan, in treating of the *primæval* globe, calls in Hindoo traditions, which he denominates orthodox, to support his geological tenets [†]. In like manner, DR RICHARDSON [‡], in writing a paper against DR HUTTON, treats extensively of what he calls a *Conspiracy* against the Scriptures; and though it is not unlikely, that some authors whom he mentions, imagined that they had overthrown the Mosaic account, by their imperfect observations, yet it must still be inquired, what relation this has to the aqueous or igneous origin of basalt, with which Dr Richardson connects it. For, after all these discussions, we must still resort to the nature of the mineral itself, since it alone can supply that truth which satisfies the mind.

Dr Richardson, who tells us that "Nature "at the Causeway changes her materials, and at "Portrush changes her style, almost every hundred

---

[*] Irish Academy Transactions, vol. VI. p. 277.

[†] De Luc's latest principles may be seen in his Travels, vol. I. p. 110, 1800.

[‡] Irish Academy Transactions, 1803, vol. IX. p. 429.

" dred yards *," concludes his last paper by terming lava a factitious substance, while he thinks that basalt bears evident marks of the hand of Nature †.

A highly praiseworthy and good divine, who was sent in 1814 to distribute the Icelandic Bible to the natives of Iceland, has, in a late work on that country, described many interesting appearances of heat with which it abounds. Besides these, however, he finds several traces of lava in the Scriptures, and has collected the passages where he thinks it is mentioned. He not only incrusts Lot's wife with that substance, but comments on 2d Peter, III. 10., and is of opinion that the earth was divided by volcanic fire in the days of Peleg ‡.—Such discussions must always be deprecated, because they connect an imperfect science with the Scriptures, and come under the just censure of Lord Bacon,

---

* Irish Transactions, vol. IX. p. 486.

† Irish Academy Transactions, vol. x. p. 92.

‡ Genesis, x. 25.

Bacon, given above; "PHILOSOPHIA PHANTASTICA, RELIGIO HÆRETICA *."

Were our present knowledge of Geology of no other use but to exhibit their absurdity, it would be of considerable advantage to the interests of science.

SOME ADVANTAGES OF THE NEW THEORY OF THE EARTH.

(Page 270.)

THE advantages of the views here given in furnishing an explanation of many geological phænomena hitherto unexplained, or accounted for by hypotheses which are often of a complex kind, are very numerous.

Both our prevailing theories have been for a long time unsatisfactory to all reflecting minds, from the imperfect nature of the evidence and the reasonings which they have brought forward. It has now become evident that

---

* See a Journal in Iceland by Dr. Ebenezer Henderson, 1818, vol. I. and Vol. II. p. 117, &c.

that neither of them possesses a right to aspire to rank as a true explanation of the construction of the world.

The theory of the appearances given in the foregoing pages, requires no aqueous or other solvent for the materials of the crust of the earth; and yet, admitting the action of water in modelling all the strata, from the oldest gneiss to the newest alluvion, it preserves all the advantages of the power of that great agent, without supposing it to act in dissolving substances for which it has no attraction.

The formation of the unstratified rocks by heat, the explanation of the origin of this heat, and its existence for the time during which it acted as the cause of the consolidation of the strata, are brought forward unincumbered by the hypothesis of a central fire constantly acting, the presence of which is opposed by so many facts connected with the temperature of our planet.

The simple principles of disintegration of the materials of granite under water, and consolidation of the strata thus formed by heat, allow us to explain a large range of phænomena; to trace many circumstances in the constitution of the strata to their causes; to find in all of them a mechanical deposit, and in the unstratified rocks marks of an igneous origin.

The same principles give rise to the explanation of the gradual transitions of one rock into another, of their alternations, and of the variety of induration and inclination seen in many of them; in fine, to the relations of the stratified with the unstratified rocks, and the intimate connection between the nature of unstratified granite and the stratified gneiss and other strata above it. Though it can be shewn that several of these strata have been deposited upon planes of inclination, yet as the action of the fused masses below them would continue for a long time, a provision thus arises for many of the disturbances and elevations visible in the strata. Their general direction in many cases it has been attempted to associate with the rotation of the globe in an easterly course.

An inquiry into the nature of crystallizing substance is a necessary part of a theory which assumes the explanation of the earth. This object, hitherto so much neglected, has supplied several conclusions which afford great assistance in forming accurate ideas of the formation of crystals, and of the strata which enclose them.

The position and nature of Basaltic Rocks lead to the relations between them and granite and other unstratified rocks; and in the structure of all these, no marks peculiar to aqueous or igneous action have been found. Hence arises the necessity of inquiring into the mode of distribution of the colours disseminated through these rocks, in order to afford a test of their origin. That origin has been found in heat, which also forms the only consolidating power.

The difference which exists in many cases between Granite and Basalt, with regard to their relations to the strata connected with them in *position*, has been stated; the former, when unstratified, not overflowing, but having had strata deposited above it in mantle-shaped forms; the latter, also elevated by heat at a subsequent æra, often overflowing above strata previously deposited, and thus depressing them, so as to give rise to their arrangement in the concave manner. An additional proof of this arises from the difference between granite veins and whin-dykes *. The former have risen up in fissures which are often ramified to a great minuteness, through the substance of layers of shistus when depositing, where it has been attempted to assign a cause for the formation of the rents. While the latter present no branching appearances, the basaltic rock having in general occupied fissures of considerable uniformity cut through strata which had been laid down, and often consolidated before the rents were made.

---

* See above, p. 225.—*Note.*

All these principles have been connected with the decay of the land, and the constant relation which this bears to the preserving causes, and the consolidation of new substances, which are daily seen in action in the world.

The objections to these views, as far as I know them, I have endeavoured to state, as well as the opposing opinions of the principal observers and theorists, in order that the reader may have before him a faithful transcript of the opinions of others, or references to their writings. It may be remarked here, that the view given of the formation of the land is not complicated with the question of a resting-place for the waters; for, the land arising gradually from them, they would occupy a higher level over the lower tracts of sea, or rest partly on lands which the heat had not elevated to the same height as our present continents.—When granitic and basaltic rocks occur interstratified with other beds, an explanation is supplied by the immediate consolidation of these unstratified rocks when disintegrating, and their deposition in strata. Beds of crystalline greenstone may thus alternate with sandstone, for the water has no powers but mechanical, and the heat would reach and melt strata of greenstone at a temperature in which sand would not even consolidate. In a similar mode, the explanation of stratified granite may follow from its deposition from the unstratified masses of the same rock near it. Strata of limestone inclosing shells may become highly crystalline, from their being more easily affected by heat than the strata of secondary clay or sandstone rocks which lie above and below them.—A third objection may arise from the limestone itself; but its origin from granites containing it has been hinted, and it occurs, when primary, in several countries in unstratified masses *, which, from their softness, may be supposed to distintegrate more rapidly and extensively than any of the other primary rocks, and thus give rise to that abundance of limestone strata which appears in the later formations.

It is another result of these views, that only *one* formation of strata seems to have taken place over the greater masses of the earth's surface. This is associated with the appearances which indicate *one* formation of shells, in a graduating series from the oldest and extinct species to those which connect or are the same with the shells of our present seas. The generations of these may be supposed to form, as the level of the waters gradually decreased, while the consolidating power was still in action below the strata; or the subsequent formation of basaltic rocks, may have affected to a distance the surrounding tracts.

---

* Jameson's Geognosy, p. 56.

While no marks of a formation from the ruins of a former state of the globe are thus observed, it is evident that several phænomena still remain to be explained. The interpretation of nature can only be supplied by the diligent study of the minute crystal and the ranges of the mountains. It is requisite, however, that our explanations should be in unison with the legitimate parts of our knowledge, or at least should not contradict them. Whatever is certain should be carefully distinguished from what is entirely hypothetical. Of the ultimate progress of a science where so much that is interesting and useful is already known, it would be contrary to the spirit of true Philosophy ever to despair.

FINIS.

P. Neill, Printer.

CORRIGENDA.

Contents, p. xiv. l. 17. *for* plains of the ocean, *read* plains and the ocean.
Page 57. l. 17. This is stated too generally; for primary limestone and serpentine occur unstratified.
—— 77. l. 15. *for* clost *read* closest
—— 95. l. 19. *after* are *insert* often
—— 149. *note*, l. 1. *for* layer *read* larger
—— 208. l. 9. *for* deposit. *read* formation.
—— 250. l. 5. *for* they *read* it
—— 262. l. 7. *for* each *read* every
—— 251. *note*, l. 4. *for* passes *read* passing

Mr Clarke Abel, in his Narrative of the late Chinese Embassy, just published, has given a detailed description of the granite veins in the shistus, which are seen on Table Mountain, at the Cape of Good Hope. From the facts which he has observed, and particularly from the relations which he has traced from granite, decomposing granite, and conglomerate, to a horizontally stratified sandstone, he has drawn inferences irreconcileable with the Wernerian and Huttonian hypotheses, and of a nature very nearly the same with those given in the preceding pages. The Geological student will find much that is interesting in Mr Abel's details. *(Narrative of a Journey in the Interior of China*, &c.—p. 287.–305.)